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ABSTRACT

The purpose of this guide is to provide teachers with information that will help them better understand how to teach science. In addition, this resource is intended to be a tool in assisting teachers in developing their science curricula and in planning their instruction. The instructional approach presented reflects the philosophy that students learn best through hands-on, inquiry-oriented experiences. This guide was developed as part of the South Carolina Basic Skills Assessment Program in Science (BSAP) and is based on the learning cycle approach. The stages of the learning cycle, examples of learning cycle lessons, development of science lessons that use a learning cycle approach, student assessment during the learning cycles, and classroom management of students when using the learning cycles are discussed. The BSAP science objectives, subskills, and related skills, a list of science activity books and guides, and supplementary articles are appended. (KR)

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BASIC SKILLS ASSESSMENT PROGRAM

BSAP SCIENCE
Teaching Through Inquiry

Charlie G. Williams, State Superintendent
An Equal Opportunity Agency

August, 1990

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BSAP SCIENCE

Teaching Through Inquiry

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Preface

The educational establishment in South Carolina has embarked on a formidable journey. Its goals are to improve the scientific literacy of all the people of South Carolina, to produce a technically capable work force that will literally draw high technology industries and the high-quality jobs that accompany these industries to South Carolina, and to produce more South Carolinians able to enter careers as scientists, engineers, and mathematicians. It begins with our greatest resource – the children of this state. Teachers will be responsible for much of what must happen, but they are not alone. They have the support and resource base of many individuals in the colleges and universities, in the private sector and government agencies, and in the State Department of Education.

Work toward these goals must begin in the earliest years of school, even pre-school, to provide the students with the type of science program that will foster their innate curiosity about the natural world. Educators cannot be satisfied with simply not "turning off" students to science. They must encourage all students to understand what science is, what scientists do, how our lives are enriched by scientific and technological advances, and how science provides us with a set of problem-solving strategies that can be used in many "non-scientific" situations. Progress will be made because we have the resources needed – children who are born with a natural curiosity, teachers who are capable of fostering that curiosity, and a desire by public officials and the general populace to improve the quality of life for all of us.

As part of implementing the Basic Skills Assessment Program in Science mandated by the Education Improvement Act, the South Carolina Department of Education and the BSAP Science Education Project have developed this resource. Its purpose is to provide teachers with information that will help them better understand how to teach science. In addition, this resource is intended to be a tool in assisting teachers in developing their science curricula and in planning their instruction.

The instructional approach presented reflects the philosophy that students learn best through hands-on, inquiry-oriented experiences. This approach enables teachers to integrate the BSAP Science Objectives in their instruction and, thus, allows students to learn about science through practical situations.

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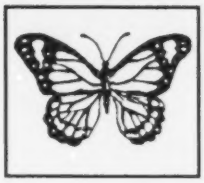


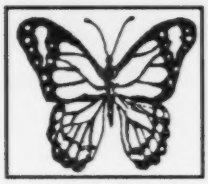
Introduction

Welcome to the world of Science – that area of study that holds hope for our future and for the future of our students. Science is more than a subject taught in the schools. It is a way of understanding and feeling more connected with our world. It is but one way of understanding and is quite different from the way that an artist or poet might view the world. Just as a poet may describe the beauty of a sunset along the coast in a sonnet, a scientist may also express this awe in an explanation of the light intensities reaching us millions of miles away from our nearest star. Both expressions have a place in our culture. Science has achieved its success because it is governed by strict rules of investigation rather than the deeply personal expressions of an artist. In addition, the results are made known to the public.

Science produces a body of knowledge which helps us learn more about the world in which we live. Technology is derived from knowledge of science and is the development and application of new discoveries in science. Some of these products and inventions have been extremely beneficial for society, and some have wreaked havoc and destruction. It is up to us to see that our students become knowledgeable consumers who will walk "softly" on this planet and make wise decisions about how science and technology are used in our society.

In the pages that follow, a plan of action is presented that will help you address the BSAP Objectives more effectively. It will encompass a science teaching model that allows you to teach all of the Objectives in an integrated manner. This model is based on the "hands-on" inquiry approach to learning. In addition, there will be information given that will assist you in moving toward a more inquiry-oriented science classroom and some practical solutions to teaching science.

So let's begin this journey!



What Are Some Challenges We Face?

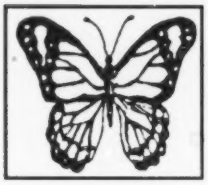
Since 1983, when *A Nation At Risk* was published by the U. S. Department of Education, it has become increasingly obvious that the nation is facing a severe problem with regard to both the *quality* and *quantity* of science instruction in the pre-college grades. Evidence of this problem is seen in two areas: a reduced number of students entering the field of science, and the low scores of American students on standardized tests.

National organizations including the National Science Teachers Association and the American Association for the Advancement of Science, and many states, began ambitious programs to increase the quantity and improve the quality of pre-college science education. South Carolina has specifically addressed the critical need for science instruction by making science a basic skill.

Reflecting national trends, the three areas listed below represent a focus for science education in South Carolina. Addressing these needs is of paramount importance in developing both a scientifically literate populace and a technologically strong work force. The areas include the need:

1. *to increase the number of students entering the fields of science, engineering and mathematics (the* Pipeline problem);
2. *to increase the number of students entering the technical fields needed to support the professional scientists, engineers and mathematicians (the* Support problem); and
3. *to increase the science literacy of the general public in order to effect more informed decisions about critical environmental, developmental, and ethical issues (the* Literacy problem).

A more general concern in all of the above areas is the need to increase the number of people from historically under-represented groups (females, minorities and physically disabled) entering science and technology oriented careers and to enhance their scientific literacy.



What Is Inquiry-oriented Science Teaching?

When a student wonders why the sky is blue or how a tiny plant can cause a crack in a sidewalk, he or she is making an inquiry about the natural processes of our earth. Inquiry science teaching begins with a question to be answered. To satisfy the needs identified in the previous section of this document, science education must advocate the use of an inquiry approach to science teaching. This method of teaching closely models actual scientific practice so that students not only learn necessary content information, but also engage in the same science process skills as does a scientist in a laboratory. Inquiry science instruction will better help our students understand science and technology and their impact upon our society and the environment. The skills students learn in the science classroom will enable them to solve meaningful problems for themselves.

Inquiry–oriented science is:

- **approaching science in a way that fosters students asking questions and arriving at solutions.**
- **involving students actively in problem solving and higher order thinking.**
- **providing students with knowledge in meaningful context.**
- **encouraging positive attitudes among students.**

Students benefit from an inquiry approach to science because each student is:

- **working with greater autonomy.**
- **engaging in a variety of science process skills.**
- **experiencing the personal excitement of discovery.**
- **discovering many aspects of the nature of science.**

Inquiry-oriented science provides:

- **a context for BSAP.**
- **a context for cooperative learning.**
- **a context for higher-order thinking.**
- **a context for the Learning Cycle.**

A Context for BSAP

The South Carolina Basic Skills Assessment Program in Science focuses on students learning science through their experiences. The four BSAP Science Objectives (see Appendix A) of science concepts, science process skills, science-technology relationships, and nature of science are addressed more effectively through an inquiry-oriented approach. This approach creates opportunities for teachers to address BSAP Science in an integrated manner.

For example, a series of inquiry activities could be designed to examine factors which affect the growth of plants. The activities would address the Science Concepts of characteristics of plants, living things interact with their environment, and living things change as they grow and develop. The other three BSAP Objectives can also be incorporated in the activities. Several science process skills can be addressed. Only through inquiry-type investigations does the student learn the difference between science processes such as observation, inference, and prediction.

In addition, these activities would address the Nature of Science. Through investigations, the student learns that science is a discipline which is based on observations and data and improves with repeated investigations. If plants were watered with varying concentrations of vinegar, Science-Technology could be addressed by incorporating discussions, readings, or speakers on the topic of acid rain.

A Context for Cooperative Learning

Cooperative learning is a teaching and learning strategy that effectively promotes student learning. Extensive research in this area demonstrates that cooperation creates fruitful learning climates and promotes the accomplishment of most cognitive and affective outcomes.

Cooperative learning can be used to:

- facilitate learning in small, inquiry-oriented task groups.
- assign roles to students in small groups.
- rotate these roles so that all group members experience the full range of responsibilities.
- make students feel responsible for their own learning as well as that of their teammates.
- foster peer teaching situations among students.
- assist the teacher in effective management of students and materials.

A Context for Higher-order Thinking

In many cases, science activities provide students with meaningful, real world contexts in which to make their decisions. By having practice in the classroom, students will then be able to use and apply these same processes through daily experiences. In teaching science through an inquiry approach, teachers provide their students with important problem-solving tools and use many attributes of higher-order thinking. Students are involved in:

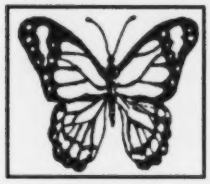
- selecting, organizing, and using strategies and processes to reach decisions.
- solving problems and making judgments about the inquiry activity they are investigating.

A Context for the Learning Cycle

Many strategies are appropriate for teaching inquiry science. Research indicates that those strategies which put students in a problem-solving situation using manipulative materials are the most effective. The Learning Cycle is a method for using teaching strategies. It has been well tested and is widely used. This approach is based on the logic that students:

- learn by engaging in hands-on activities which provide opportunities for "doing science".
- benefit from motivational activities which enable them to explore science concepts.
- need reinforcement activities with real-life examples to help them apply what they have learned.

In the next section, the Learning Cycle will be examined in greater detail.



What Are the Stages of the Learning Cycle?

While there are several variations of the Learning Cycle, a three-phase approach is being recommended for teaching the BSAP Science Objectives. The three phases are outlined below. A detailed description of each phase of the Learning Cycle is provided on the following pages. Two examples of lessons which incorporate the Learning Cycle are then described.

Exploration Phase

> *concept(s) explored*

> *activity-oriented*

> *divergent questions posed*

Concept Development Phase

> *concept(s) developed and explained*

> *direct instruction by teacher*

> *vocabulary and terms defined*

Concept Application Phase

> *concept(s) extended or applied*

> *real world application*

> *student-student interactions*

Exploration Phase

In the Exploration Phase, the concept is introduced to students through an inquiry-oriented activity. During this motivational phase, students are given ample time to manipulate materials and explore ideas without specific instructions from the teacher. Thus, students "discover" the concept as a result of their experiences in the activity. This is in contrast to a more traditional way of beginning a lesson through lecture or reading.

The Teacher's Role

During this stage, the teacher's role is more that of a group facilitator than simply a disseminator of knowledge. As a facilitator, the teacher monitors group activities and guides students' actions and thoughts through appropriate questioning. Any questions posed to students should be in an open-ended format, thus providing opportunities for students to explore the concept further and to come up with their own answers.

The Students' Role

While exploring the concept, students should make observations and collect data. The data gathered by the students should be recorded and organized in an easily readable format, e.g., table or chart.

The Classroom Arrangement

Generally, if the Exploration Phase is to begin with a hands-on activity, it should be conducted with students in small groups. The small group arrangement allows opportunity for greater student involvement and provides assistance to the teacher in managing student behavior. In some instances, the teacher might also wish to begin this Phase with a motivational open-ended question to the whole class before progressing to a small group arrangement.

Exploration Phase

The teacher is:	While the students are:
■ engaging student interest by providing motivating experiences. ■ facilitating discussions of small groups by **not** providing "all the answers". ■ posing open-ended questions to individuals or groups. ■ observing and monitoring student behavior.	■ investigating the concept by hands-on experiences. ■ making observations and recording data. ■ beginning to explain the concept in their own words. ■ developing a common set of experiences.

Concept Development Phase

In the Concept Development Phase, students try to find patterns that exist in the data they have collected and in the observations they have made. It is important that the concept is developed as an outgrowth of student observations made during the Exploration Phase.

The Teacher's Role

During this stage, it is important to note that the teacher might need to provide more guidance to students by getting them to focus in on the essential attributes of the concept. This can be done by helping students filter out nonessential or irrelevant data and observations and by focusing on the important outcomes of the activity.

The Students' Role

Each student should be actively involved in looking for patterns in the data and attempting to make interpretations from the data. Appropriate terminology and vocabulary should be used by the students to describe their experiences.

The Classroom Arrangement

Whole class grouping generally works well in this phase of the Learning Cycle. Using this arrangement, the teacher can introduce the concept with the appropriate terminology and vocabulary to the entire class. Instruction can be provided using a number of resources including textbooks, audio-visual aids, and other materials.

Concept Development Phase

The teacher is:	While the students are:
■ giving information. ■ guiding whole class discussions. ■ providing explanations for student experiences. ■ defining appropriate terminology and vocabulary.	■ beginning to organize and look for patterns in data collected. ■ using terminology and vocabulary to explain their experiences. ■ sharing experiences with other members of the class.

Concept Application Phase

The Concept Application Phase is similar to the Exploration Phase and should provide additional activities for students to reinforce and apply the newly learned concept. As an outcome of this phase, students should figure out connections between the broad scientific principles and their daily lives.

The Teacher's Role

During this phase, teachers should assist students in applying the science concepts developed and information learned during the previous phases. To accomplish this, the teacher should present a new problem or situation to students and ask them to use the concepts to solve the new problem or apply the information to a new situation.

In planning their lessons, teachers should keep in mind that the Application Phase can be used as a time to begin the exploration of a new, related topic through the introduction of another inquiry activity. Thus, the Concept Application Phase of one lesson can become the Exploration Phase of the next lesson.

The Students' Role

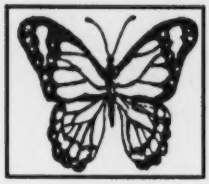
Students should be using the newly acquired concepts and information in an investigative or exploratory activity. They are not supplied with all the answers but are encouraged to use the information they have acquired to offer an explanation to the new problem presented.

The Classroom Arrangement

As in the Exploration Phase, small class arrangements work well. The small groups facilitate cooperative efforts among students and promote students sharing their ideas.

Concept Application Phase

The teacher is:	While the students are:
■ providing opportunities for students to apply the newly learned concept. ■ facilitating student discussion by posing divergent questions. ■ observing and monitoring student interactions.	■ actively involved in the learning process. ■ using the newly learned concepts to explain new situations in terms of prior experiences. ■ involved in discussions to construct deeper meaning of the concept.



What Are Examples of Learning Cycle Lessons?

Example One

This lesson illustrates each phase of the Learning Cycle and is appropriate for grades 4-6. The lesson is designed to explore the *life science concept* of relationships between living things and their environment and could be used as part of a unit on this concept. It is assumed that students have already been introduced to concepts such as population, habitat, and environment.

This lesson also addresses some aspects of the other BSAP Science Objectives. Several *process skills* are used in the investigations; these include making observations, constructing tables to communicate data, interpreting data, and making predictions. The impact of *science and technology* on self, society and the environment is addressed through examining the impact of pollution on a community. One aspect of the *nature of science* is included when students use their observations and data to draw conclusions about their investigations. Steps for teachers to follow for each phase of the Learning Cycle are described.

Exploration Phase

1. *Ask students a motivating question, such as "Suppose there were only a certain amount of food available for animals to eat. What do you think would happen?"*
2. *Arrange the students in small groups. Have the students pretend to be birds feeding on seeds. To do this, each group is given 16 bird cards and 16 kernels of corn. Each group is told to begin with four birds and 16 kernels of corn. The groups should divide the 16 kernels of corn equally among the four "birds" and then record in a data table the number of kernels of corn that are available for each bird.*
3. *Next, tell the students to pick up four more bird cards so that the group now has eight birds. Have the student divide the 16 kernels of corn equally among the eight "birds". The students should determine how many of the 16 kernels of corn each bird now has to eat.*

4. *Finally, the remaining eight bird cards are included. Have the students divide the 16 kernels among the 16 "birds". The students should determine how many of the 16 kernels each bird eats.*

5. *Ask students to look for any patterns in the data they collected by constructing a table such as the one below.*

Trial	Number of Birds	Kernels of Corn per Bird
1	4	4
2	8	2
3	16	1

Concept Development Phase

1. *In a whole class arrangement, ask each group of students to share their data with the class. Encourage the class to look for patterns in the sets of data. Is the pattern observed by the class different from what the students observed in their small groups? Have students discuss the relationship between the number of birds and the amount of food available for them to eat. What conclusions can the students make?*

2. *Introduce and define the term "limiting factor". Ask the class what they think the "limiting factor" is in their activity. Have the class discuss other things which may be limiting factors in an environment.*

Concept Application Phase

1. *Note that all of the birds shared the corn equally, if the students do not bring up this point in their discussion.*

2. *Ask the students to predict what would happen if the birds did not get to share the food equally.*

3. *In small group arrangements, give each group 16 kernels of corn. Allow each group member to be a bird. Tell each student to pick up as many kernels of corn as they wish when you say "Go". Have students record the number of kernels each bird collected in their group.*

4. *Tell students their bird "died" if it did not get at least 4 kernels of corn.*

5. *Have students share information about the numbers of birds that "died". Discuss the effects that a limiting factor may have on populations of plants or animals.*

6. *Encourage students to discuss how a limiting factor might affect them (e.g., "What would happen if a drought occurred and farmers could not grow enough food for people to eat?").*

Example Two

The following example of a Learning Cycle illustrates all three phases and could be used in a unit on soil formation and erosion in an eighth grade classroom. The lesson involves a modified role-play situation. In planning this lesson, it is assumed that students have already been introduced to concepts such as soil texture, soil profiles, and soil erosion.

This lesson addresses several aspects of all four BSAP Objectives. It addresses the *earth-space concept* of the properties and characteristics of the earth including its surface processes. Several *process skills* are addressed, including observing, making inferences, making predictions, generating questions, identifying necessary information, and formulating hypotheses. The impact of *science and technology* on self, society, and the environment can be addressed through examining the impact of factors such as the agricultural overuse of the land and its effect on soil fertility. The *nature of science* can be addressed by discussing with students the use of a systematic approach to solve the problem presented to them.

Exploration Phase

1. *Show students pictures or slides of good and poor growth of the same crop, e.g. cotton. Ask questions like:*
   a. *What differences can you observe in the pictures or slides?*
   b. *What are some possible explanations for these differences?*
   c. *What are the implications of these pictures or slides to people?*
2. *Tell each group of students that they are going to be put into a situation and will be taking on the role of someone else. For example, the teacher might tell the group:*
   a. *You are soil scientists in your county's agricultural research office. You have just received information that cotton, an important crop in your county, can no longer be grown in your county because of some problem with the soil.*
   b. *How will you determine exactly what the problem is; and what, if anything, can be done to eliminate or reduce the problem?*

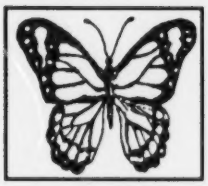
3. *Allow the students about 20 minutes to discuss the task among themselves. If they seem to be having trouble getting started after 10 minutes, ask some leading questions, like:*
    a. *What information do you need to solve the problem?*
    b. *What are some possible factors or variables that might be affecting the soil's capacity to grow cotton?*
    c. *Choose one variable to be tested. How would you design an experiment to determine if that variable is affecting the soil's capacity to grow cotton?*
    d. *If the variable you tested was, in fact, found to be one reason the soil could not grow cotton, what would you do to reduce or eliminate the problem?*

Concept Development Phase

1. *Allow each group to explain briefly how they attacked the problem. Have the class critique each group's approach in a non-derogatory way, offering only constructive criticisms.*
2. *Define the term "fertility".*
3. *List the factors that affect soil fertility.*

Concept Application Phase

1. *Have the class list the items that they think are made of cotton or cotton by-products.*
2. *Have the students write a paragraph or short story describing a day without any cotton products.*



How Can Teachers Develop Science Lessons That Use a Learning Cycle Approach?

Teachers can use existing materials from textbooks, curriculum projects, and other resources to develop science lessons that incorporate the Learning Cycle approach. The following guidelines should be considered in developing a Learning Cycle lesson.

1. **Select lesson you want to teach.**

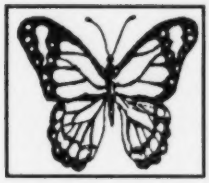
2. **Identify the phases of the Learning Cycle that are not included in the lesson you selected.**

3. **To modify your lesson to teach all phases of the Learning Cycle, select additional activities that can be used to teach the missing phases. For the Exploration and Concept Application Phases, activities identified as hands-on, discovery and enrichment activities suggested in textbooks, supplemental lab books or teacher activity books may be appropriate. (See Appendix B for specific resources.)**

4. **Consider the kinds of class arrangements that you wish to use for each phase of the Learning Cycle. Possible student arrangements include whole class, small group, and individual.**

5. **Give some consideration as to how you are going to divide your class periods to accommodate the three phases of the Learning Cycle. Some cycles can be completed in one class period, whereas others may require an extended period of time.**

6. **As you begin to develop Learning Cycles, consider the possibility of letting the Concept Application Phase of one lesson lead into the Concept Exploration Phase of the next lesson. This allows even greater opportunities for concept development and application. Additional information for developing Learning Cycle lessons may be found in "The Learning Cycle" and "The Learning Cycle: Making It Work". (See Appendix C for articles.)**



How Can Students Be Assessed during the Learning Cycle?

Assessing the progress of student learning is an important and integral part of the Learning Cycle. Through assessments, teachers can obtain useful information for planning, monitoring, and modifying instructional units and lessons involving the Learning Cycle. Assessments also provide important information to evaluate student learning, skills, and attitudes, as well as to evaluate the effectiveness of instructional units and lessons.

When to Assess

Assessments can be made at various times during the Learning Cycle to serve several basic instructional purposes. Teachers may assess students:

- at the beginning of the Learning Cycle, to diagnose students' prior and prerequisite knowledge and skills related to the instructional objectives (diagnostic assessment).
- during the Learning Cycle, to monitor student learning (formative assessment).
- at the end of the Learning Cycle, to determine how well students have learned the science concepts, relationships, and skills addressed in the instructional objectives (summative assessment).

How to Assess

A variety of assessment strategies which assess cognitive, psychomotor, and affective outcomes can be used during all three phases of the Learning Cycle. These strategies are discussed in the remainder of this section.

Teacher Questioning

Asking the right questions at the right time is a powerful tool for both facilitating and assessing learning. Open-ended questions which prompt students to apply, analyze, synthesize, and evaluate promote higher-order thinking.

Some suggestions for assessing student learning, skill performance, and attitudes through teacher questioning follow:

- preparing a list of possible questions ahead of time, making sure that higher level thinking questions are included.
- allowing plenty of time for students to respond. If students have more "wait time", they are more likely to provide richer, more developed responses.
- allowing several students to respond to the same question. In this way, the teacher does not automatically evaluate the "correctness" of a single student response to a question.
- making notes about students' responses. These responses can reveal students' current conceptions and thought processes.

Teacher Observation

In the course of a lesson or activity, teachers constantly observe students to monitor progress and to determine whether and how to adjust the instruction to facilitate learning. Teacher observations can provide information about students which is not readily evident in paper-and-pencil assessments. Sharply focused observation can be effective and illuminating and enable teachers to make some inferences about students' understanding and conceptions.

Focused observations are also invaluable for providing teachers with information about students' abilities and attitudes, such as their:

- ability to organize and explain ideas orally.
- willingness to cooperate in groups.
- ability to use manipulatives.
- attitudes toward and interest in learning.

Student Writing

Writing is a basic skill in science class and a useful tool for assessing students' science learning and attitudes. Examples of student activities or tasks which involve writing are:

- descriptions of observations and other science activities.
- entries in a science journal which may describe the student's science learning or interests related to science. (See article in Appendix C, "Wrap Up With a Writeup".)
- reports of science investigations or science topics.

Objective Tests

Objective test items are commonly used and can be effective, efficient ways to assess student learning at the comprehension and application levels. Types of test-item formats include:

- multiple-choice items.
- matching items.
- short answer items with specific correct answers.

Open-Ended Test Items

Open-ended test items which can be used in conjunction with objective test items are especially appropriate for assessing higher levels of student learning. This assessment strategy allows students to do more comprehensive thinking and to generate (not select) more complex responses. Examples of open-ended assessment tasks are:

- designing a science investigation to solve a problem situation.
- inventing and designing a technology (product or process) to solve a problem situation.
- making inferences and predictions about a situation.

Performance Assessment

In performance assessments, students demonstrate their learning by doing. For assessing particular types of science instructional objectives, such as the process skills objectives, actual performance assessment may provide a more valid indication of student learning than other assessments. In a performance-assessment situation, students are given a task that may take from a half-hour to several days to complete. Performance tasks can be supervised by the teacher or by outside observers. Following are examples of performance-assessment tasks in which students can demonstrate aspects of science learning:

- using science equipment such as measuring tools, microscopes, etc.
- constructing tables and graphs.
- conducting science investigations.
- developing a product designed to solve a problem.

Student Affective Assessment and Self-Assessment

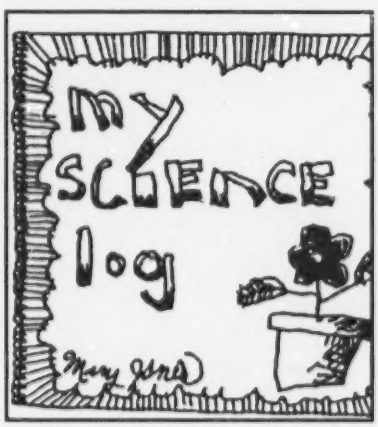
An important part of learning in science involves the student's ability and willingness to assess his or her own progress and feelings toward science learning. Self-assessments encourage students to become aware of their own learning and provide valuable affective information to teachers.

Some examples of student self-assessment activities which can be done with the individual, small groups, or the entire class are:

- drawing pictures (especially for young children).
- completing questionnaires, with scaled responses or open-ended questions.
- keeping journals of science experiences.

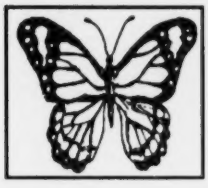
Student Portfolios

Student portfolios are not new to teachers. Many teachers keep folders of student work to document student progress. Items included in portfolios can serve as material for assessment, as well as a resource for explaining test scores. Thus, student portfolios represent an important and relevant part of assessment.



Teachers may specify what should be included in a portfolio, but students should also be allowed to add items of their own choosing. Portfolios might include:

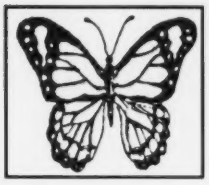
- written assessments.
- performance-assessment evaluations.
- student self-assessments where appropriate.



What Are Some Ways to Manage Materials during the Learning Cycle?

The efficient distribution of materials is critical if the science lessons are to go smoothly. If a lengthy delay is encountered, the class may get bored and behavior problems may develop. There are several ways to enhance the distribution of materials.

- The materials can be placed on trays (large meat trays from the grocery store work well) prior to science time. Then the trays can be distributed to teams quickly.
- Another strategy is to have each team appoint a member (or members) to get all or a portion of the supplies. If this strategy is used, it is helpful to place the materials in more than one location around the room to avoid crowding. It is also helpful to discuss the problem with the class.
- Clean-up at the end of the science lesson is also critical. If the materials are just dumped in a pile, then it will take up your valuable time to put them back into a usable form. In addition, if the materials are not put away neatly, then the possibility of materials being lost is increased.
- It is a good idea to have an inventory card that will identify the materials and where they belong. This allows for a quick visual check to make sure that a magnet isn't "lost".
- One technique that can work is to assign the "inventory check" job to reliable students as a part of the clean-up.
- Effective directions contribute greatly to the success of an activity. It is best to give directions *before* the materials are distributed to the students. Otherwise, some students may be paying more attention to the objects than to your directions.
- Use a set of the objects to demonstrate the directions so that the students can see what is to be done with the materials. The directions should be clear and in sequence.
- Additional strategies for managing people and materials are discussed in "Using Inquiry Task Groups in Elementary Science". This article is found in Appendix C.



What Are Ways to Manage Students during the Learning Cycle?

It is well established that students who are actively involved in their learning exhibit far fewer discipline problems than those who are in a more passive mode. It's just common sense – boredom leads to discipline problems. When students first begin to engage in "hands-on" science, behavior problems may increase initially because of the newness of the approach. With time, the behavior problems always drop to a level below that found in a more traditional science class. Your normal rules of correct behavior may have to be modified slightly to allow for "good noise" to thrive, while keeping distractions to a minimum.

The real key to your success as an inquiry teacher is *the way you manage your classroom arrangements through the Learning Cycle.* It is preferable to arrange your class in a way that promotes cooperative learning. Such arrangements model the enormous cooperation the scientific community employs in searching for new discoveries. A further discussion of classroom arrangements may be found in an article entitled "Cooperating Classroom". This article may be found in Appendix C.

Classroom Arrangements

The kind and variety of student grouping arrangements are very important environmental factors for a teacher to control. Traditional ability grouping based on student academic level is a common example of the use of the small group arrangement. There are several alternatives, however, to traditional ability grouping.

Whole Class Arrangement

In the whole class arrangement, the teacher is in an excellent position to give directions, use the board or displays, or give a short discussion or demonstration. This arrangement is best used when all students need to receive the same information and when the expectations for all student are about the same. In other words, whatever the teacher presents to the whole class is at a level so that all students can understand and succeed.

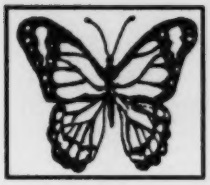
Within the whole class arrangement, students can still work independently. The teacher gives each student the same science activity, and the teacher serves as a monitor. The type of activity can vary widely from traditional "seat work", such as filling out a science work sheet, to problem-solving challenges or science puzzles which require more creativity.

Small Group Arrangement

Small group arrangements provide you with the largest number of options to facilitate student activity and learning. Group size can vary from pairs to a large number depending upon the learning objective. The criteria for selecting students to be members of a group also varies. Consider mixing students of different "ability levels" in some small groups to develop peer teaching situations. Small groups are highly useful for manipulative activities such as lab investigations, field trips, and science simulations.

Individual Arrangement

In this arrangement each student is working independently on a task with different learning objectives. This is in contrast to the whole class arrangement where all students are working independently, but on the same learning objective. Science learning stations and independent science projects are two examples of this form of management. As in the small group arrangement, this form allows excellent opportunity for manipulative activities and teacher observation.



How Can Teachers Acquire Appropriate Resources?

Acquiring Appropriate Activities

Inquiry-oriented activities allow the student varying degrees of freedom to explore relationships and truly develop or invent concepts. In such activities, there is no "correct answer", and students might discover concepts on their own. Many of the newer textbook series have excellent inquiry-oriented activities. There are other sources as well which contain a higher proportion of inquiry-oriented classroom and/or field activities. Within the State, numerous activity books have been published with school district support or through State or federal funding projects. Many other activity books on a national level have been published, and some examples of these are listed in Appendix B.

Acquiring Appropriate Materials

After finding appropriate activities, we then acquire the materials needed to implement them. It is a common impression that implementation of an inquiry-based science program requires expensive equipment and materials. Nothing could be farther from the truth.

You may find, for example, that beakers are called for in an activity. Beakers are expensive! In many cases you can substitute baby food jars. Many activities calling for beakers can even be successfully implemented with clear plastic cups, reducing the danger of breakage and accidents related to the use of glassware. Many activities, in fact, use nothing but free or inexpensive materials that are available from department, hardware, or grocery stores. (In Appendix B, there is a publication *Science on a Shoe String* which contains mostly activities that require only free, inexpensive, or easily available materials.)

Planning

Appropriate long-term planning and scheduling of activities will allow you to elicit donations of materials (jars, pie tins, styrofoam meat trays, cardboard boxes, etc.) from parents.

If you knew at the beginning of the school year which activities you would be implementing and what materials would be needed, you could send lists of needed materials home with your students. By having students and parents assist in procuring needed material, you instill in both a sense of ownership in the science program.

Purchases

Some material and equipment will have to be bought. This is especially true in the upper grades where equipment like beakers, microscopes, hot plates, and some chemical supplies are essential. Students must experience science at this level in a realistic laboratory situation.

Funding

Encourage your principal to designate a budget for science. Some additional suggestions for funds include:

- funds from your PTA or PTO.
- funds from local businesses and/or industries, which are often willing to support elementary/middle school science programs.
- funds from a local private sector partner through Adopt-A-School or Local Alliance programs.

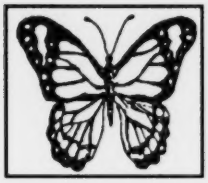
Utilizing Human Resources

Finally, there are the human resources – those individuals who are in science-related fields or have an interest in science education.

These people can significantly augment your science program. Many businesses, industries and government (local, state, federal) agencies are eager to offer guest speakers and/or field trip experiences, as well as their promotional literature in the form of posters, brochures, manipulative materials and/or special interest activities.

Inviting guest speakers to your class can be a frustrating experience. Unless extra-ordinary care is taken, too often a well-meaning speaker presents inappropriate material for the subject or grade level. Students, teachers and guest speakers all suffer. A resource to help alleviate this problem is entitled *Effective Guest Speakers ... Perfecting the Partnership.* This document may be available from your school or district. If not, it is available from the State Department of Education in the Office of Leadership and School Improvement.

Another available resource is the parents of your students. Inquire as to the parents' backgrounds and careers in industry, medicine, technology, and other fields related to science. Invite those parents who can share their science expertise to visit your classroom.



What Can Teachers Do to Become Better Prepared?

It's a common belief that "teachers teach the way they were taught". Many surveys indicate that most teachers' learning experiences in science were restricted to a small number of lecture-oriented courses with few laboratory experiences.

The result is a lack of science content background and poor models of the teaching strategies required to teach an inquiry-oriented science program. It's like asking a teacher to teach a foreign language with no previous language training! Therefore, until teachers have experienced the excitement of discovery in inquiry-oriented science courses, they are facing yet another, even bigger challenge.

The successful implementation of an inquiry science program in the elementary and middle schools is going to require teachers to know more science content, to develop better science process skills, to understand the real nature of science, and to be able to relate science and technology to each other and to ourselves, our society, and our environment.

Teachers don't have to wait, however, to move in the direction of an inquiry-oriented science program. They can begin to move while they are still learning!

Ways to Get Knowledge and Experience

Teachers are very fortunate in South Carolina to have more opportunities for these types of experiences than do teachers in most other states. Since 1983, the General Assembly has provided approximately $1 million per year for programs to alleviate teacher deficiencies in designated Critical Teaching Needs (CTN) areas.

Funds are available through the CTN program for districts to provide certificate renewal or college credit courses for teachers. Funds are also available at the district level through the federally funded Dwight D. Eisenhower Mathematics and Science Education Act (Title II) to provide teachers with in-service workshops, formal course work, and other opportunities that will help enhance teacher science competency.

Teachers can contact their district science liaison or district staff development coordinator and request for additional staff development activities. These may take the form of a course or workshop in a science-content area or one dealing with science methods.

Teacher participation in state, regional, or national professional organization meetings is highly recommended as a means of improving science instruction.

Appendix A

BSAP Science Objectives, Subskills, and Related Skills

Science Concepts (CN)

The student can apply science concepts.

CN1: The student can comprehend and apply basic LIFE SCIENCE concepts.

CN1-A: The student can comprehend and apply the concept that living things have characteristics and structures which make them similar to, and distinct from, other living and nonliving things.

- A1: Living things, in general, have characteristics and structures by which they can be described and which make them distinct from each other and from nonliving things.
- A2: Animals have characteristics and structures by which they can be described.
- A3: Plants have characteristics and structures by which they can be described.

CN1-B: The student can comprehend and apply the concept that living things are interdependent with each other and their environment.

- B1: Living things are interdependent with their environment for basic needs.
- B2: Living things interact with each other and the environment in which they live.
- B3: Living things are dependent on each other for food.
- B4: Living things are adapted to survive in their particular environment.

CN1-C: The student can comprehend and apply the concept that living things are in continuous change.

- C1: Living things change as they grow and develop.
- C2: Populations and communities change as the environment changes.

CN2: The student can comprehend and apply basic EARTH-SPACE SCIENCE concepts.

CN2-A: The student can comprehend and apply the concept that the earth, solar system, and universe have properties which characterize their compositions and structures.

- A1: The earth's air has properties by which it can be described.
- A2: The earth's water has properties by which it can be described.
- A3: The earth's land is composed of various materials and natural resources with properties by which they can be described.
- A4: The earth's crust has various features by which it can be characterized.
- A5: The structure of the earth's interior has properties by which it can be described.
- A6: Features of the earth's surface can be used to describe the earth's history.
- A7: The solar system is composed of celestial objects that have properties by which they can be described.
- A8: The universe contains all matter that exists and has properties by which it can be described.

CN2-B: The student can comprehend and apply the concept that interactions on the earth and in the solar system may result in changes.

B1: The earth is surrounded by an ocean of air that is in constant motion and interaction with the land and water.

B2: The earth's water is continually changing form as it interacts with the earth's land and air.

B3: The earth's surface features are continually changing as a result of processes that are occurring on the surface of the earth.

B4: The earth's surface is continually changing as a result of processes that are occurring in the interior of the earth.

B5: The earth's weather is caused by interactions of heat energy, air pressure, wind, and moisture in the atmosphere.

B6: Interrelationships among the earth, the sun, and the moon cause changes on the earth.

CN3: The student can comprehend and apply basic PHYSICAL SCIENCE concepts.

CN3-A: The student can comprehend and apply the concept that matter, forces, and energy have properties by which they can be characterized.

A1: Matter, in general, has properties by which it can be described.

A2: Matter exists in a variety of forms which have properties related to its structure.

A3: Forces, in general, have properties related to interactions with matter.

A4: Energy, in general, has properties by which it can be described.

CN3-B: The student can comprehend and apply the concept that matter, forces, and energy interact and may result in changes.

B1: Forces explain many of the interactions involving matter and energy.

B2: Physical and chemical changes are a result of interactions involving matter, forces, and energy.

B3: Energy changes as a result of interactions involving matter and energy.

Science Process Skills (PR)

The student can apply science process skills.

PR1: The student can comprehend and apply BASIC science process skills.

PR1-A: The student can comprehend and apply the skill of making accurate qualitative and quantitative observations.

PR1-B: The student can comprehend and apply the skill of classifying objects, organisms, and events based on observations and data.

PR1-C: The student can comprehend and apply the skill of making inferences about objects, organisms, or events based on observations and data.

PR1-D: The student can comprehend and apply the skill of making predictions about objects, organisms, or events based on observations, data, and inferences.

PR1-E: The student can comprehend and apply the skill of communicating information.

PR2: The student can comprehend and apply INTEGRATED science process skills.

PR2-A: The student can comprehend and apply the skill of generating questions about a problem that can be investigated.

PR2-B: The student can comprehend and apply the skill of identifying information needed to solve problems.

PR2-C: The student can comprehend and apply the skill of identifying manipulated, responding, or controlled variables.

PR2-D: The student can comprehend and apply the skill of formulating hypotheses.

PR2-E: The student can comprehend and apply the skill of operationally defining variables.

PR2-F: The student can comprehend and apply the skill of formulating strategies to test a hypothesis.

PR2-G: The student can comprehend and apply the skills of interpreting data and drawing conclusions.

Science and Technology (ST)

The student can analyze the relationships between science and technology, as well as the relationships of science and technology to self, society, and the environment.

ST1: The student can comprehend, apply, and analyze basic concepts about technology and relationships between science and technology.

ST1-A: The student can comprehend and apply basic concepts about technology.

ST1-B: The student can comprehend, apply, and analyze relationships between science and technology.

ST2: The student can comprehend, apply, and analyze basic relationships between science/technology and self, society, and the environment.

ST2-A: The student can comprehend, apply, and analyze the relationships of science/technology to self, society, and the environment.

ST2-B: The student can comprehend, apply, and analyze the relationships of self and society to science/technology.

Nature of Science (NS)

The student can demonstrate a comprehension of the nature of science.

NS1: The student can comprehend and apply basic concepts about the nature of science.

NS1-A: The student can comprehend and apply concepts related to characteristics of science knowledge.

NS1-B: The student can comprehend and apply concepts related to the development of science knowledge.

Appendix B

Science
Activity Books
and
Guides

Science Teacher Resources – Activity Books and Guides

Many of these resources use an inquiry, Learning Cycle approach to science instruction. Others will simply contain hands-on science activities that have to be adapted to a Learning Cycle format.

Activities in Energy
Agriculture and Natural Resources
1205 Pendleton St
Columbia, SC 29201
803-734-0445
Two quick activities are offered for grades 3-9 used to either introduce or reinforce energy concepts.
Free of Charge.

Activities in the Life Sciences
Children's Press
1224 West Van Buren Street
Chicago, IL 60607
800-621-1115
Book experiments for living organisms. Grow bacteria, calculate the rate of seed germination, measure the height of trees, feed a stinging hydra, set up a food chain, make prints of human fingers and feet, etc.
$13.00

Adaptations, Outdoor Biol. Instruct. Strategies
Delta Education, Inc.
P.O. Box M
Nashua, NH 03061-6012
800-258-1302
Module of seven activity folios: Animal movement in water, Desert water keepers, Food grab, Hold it, Invent an animal, Invent a plant, and Seed dispersal.
Module, $15.60

Adventures with Atoms and Molecules
Enslow Publishers, Inc.
Bloy Street & Ramsey Ave., PO Box 777
Hillside, NJ 07205
201-964-4116
Book of experiments for physical science and chemistry. Students learn about the properties of molecules, how temperature affects the behavior of molecules, and how the molecules react in different liquids.
$13.95

All Around: Learning Through Science
Teacher's Laboratory
PO Box 6480, 214 Main Street
Brattleboro, VT 05301-6480
802-254-3457
Set of 24 activity cards using observation, exploration and investigation skills for studying plant and animal habitats.
Cards and Teachers Guide: $27.00

Amazing Mammals, Ranger Rick's NatureScope
National Wildlife Federation
1412 16th Street, NW
Washington, DC 20036-2266
202-797-6800
Guide of 46 lessons on characteristics of mammals, their biology, behavior and interaction with humans.
Guide: Parts I and II, each $6.00

Animal Behavior, Outdoor Biol. Instruct. Strategies
Delta Education, Inc.
PO Box M
Nashua, NH 03061-6012
800-258-1302
Module of eight activities: Ants, For the Birds, Isopods, Jay Play, Leapin' lizards, Scram or Freeze, The Old White Sheet Trick, and Web it.
Module: $17.15

Animal Defenses
Great Explorations in Math and Science (GEMS)
Lawrence Hall of Science
Berkeley, CA 94720
415-642-7771
Guide on the defensive structures and behaviors of dinosaurs and dogs, cats, turtles, lizards, and other animals.
Guide: $6.50

Aquatic Animal Behavior
Delta Education, Inc.
PO Box M
Nashua, NH 03061-6012
800-258-1302 or 603-889-8899
Module of seven activities: Animal Movement in Water, Attract a Fish, Damsels and Dragons, Hopper Circus, Salt Water Revival, Water Breathers, and Water Striders.
Module: $15.60

Astronomy Adventures, Ranger Rick's NatureScope
National Wildlife Federation
1412 16th St, NW
Washington, DC 20036-2266
202-797-6800
Guide containing 29 lessons on the study of stars, planets, and astronomical phenomena through the use of experiments, games, simulations, and demonstrations.
Guide: $6.00

Audubon Zoo Activity Books
Audubon Park and Zoological Garden
PO Box 4327
New Orleans, LA 70178
504-861-2537
Activity books: Asian Domain, Grasslands of the World, World of Primates, World of Birds, Wisner Children's Village discovery book and Louisiana Swamp Exhibit Discovery Book. Used in conjunction with zoo visit. $2.50 per Activity Book

Backyard, Outdoor Biol. Instruct. Strategies
Delta Education, Inc.
P.O. Box M
Nashua, NH 03061-6012
800-258-1302
Module includes eight activities: Birdfeeder, Flower power, Food grab, Invent an animal, Isopods, Sticklers, Super soil, and Water holes to mini-ponds.
Module $18.65

Beastly Neighbors: About Wild Things in Cities
Little, Brown and Company
34 Beacon Street
Boston, MA 02108
800-343-9204
Activity book on plant & animal environments; includes windowsill seed garden, feeding birds, growing wildflowers, making a nest box for squirrels, etc.

Beginning Experiences in Architecture
Van Nostrad Reinhold Comp., Inc.
115 Fith Avenue
New York, NY 10003
How to teach architecture in elementary school, using a variety of materials. Projects designed to allow children to see the dynamics of forms and planes in space.Beautifully illustrated with photographs.

Behavior of Mealworms, Elementary Science Study
Delta Education, Inc.
PO Box M
Nashua, NH 03061-6012
800-258-1302
Guide to help in the study of larval insects, in this case mealworms. It contains extensive background information on mealworms and instructions for their care. Kit, Activity Cards and Readers also available.
Guide: $8.00, Kit: $18.00

Bet You Can! Science Possibilities to Fool You
Avon Books
1790 Broadway
New York, NY 10019
Sixty-two tricks with apparently unlikely results, and their scientific explanations.

Bio-Crafts, Outdoor Biol. Instruct. Strategies
Delta Education, Inc.
PO Box M
Nashua, NH 03061-6012
800-258-1302 or 603-889-8899
Module of nine activities: Birds Nests; Bugs, Worms; Environmental Sun Prints; Food Grab; Invent an Animal; Invent a Plant; Seed Dispersal; and Web Weavers.
Module: $18.65

Birds, Birds, Birds! Ranger Rick's NatureScope
National Wildlife Federation
1412 16th Street, NW
Washington, DC 20036-2266
202-797-6800
Guide of 25 lesson plans with supplemental student activity sheets that provides an introduction to the study of ornithology.
$6.00

Blood & Guts: Working Guide to Your Insides
Little, Brown and Company
34 Beacon Street
Boston, MA 02108
800-343-9204
Guidebook of 70 experiments where children become acquainted with their own anatomy.
$7.95

Breakwaters & Bays, Outdr. Biol. Instruct. Strats.
Delta Education, Inc.
PO Box M
Nashua, NH 03061-6012
800-258-1302
Module of seven activities: Beach Zonation, Clam Hooping, Crawdad Grab, Flocking to Food, OBIS Oil Spill, Rock Pioneers, and Water Breathers.
Module: $15.60

Brine Shrimp, Elementary Science Study
Delta Education, Inc.
PO Box M
Nashua, NH 03061-6012
800-258-1302
Guide that introduces children to the study of living things and to the workings of a life cycle. Students maintain a saltwater environment in which these tiny crustaceans hatch, grow, and eventually produce offspring.
Guide: $4.50, Kit: $37.00

Buzzing a Hive
Great Explorations in Math and Science
Lawrence Hall of Science, University of California
Berkeley, CA 94720
415-642-7771
Children discover the complex social behavior, communication, and hive environment of the honeybee; the parts of a honeybee's body; and how bees adapt to the larger world.
Guide: $11.00

CESI Sourcebook II
ERIC Clearinghouse, Science, Math, & Envir Ed
Ohio State University, 1200 Chambers Rd, 3rd Floor
Columbus, OH 43212
614-292-6717
Book offers ideas to improve instruction and suggests ways to increase student abilities. Sourcebook of activities such as making temperature meters, design and build a fish, and invent a civilization.

Campsite, Outdoor Biol. Instruct. Strategies
Delta Education, Inc.
PO Box M
Nashua, NH 03061-6012
800-258-1302
Module of six activities: A Better Fly Trap, Ants, Jay Play, Silent Stalking, and Who Goes There? Children investigate behavior of flies, ants, jays, night-flying insects, and other animals.
Module: $14.00

Candles
Teacher's Laboratory
PO Box 6480, 214 Main Street
Brattleboro, VT 05301-6480
802-254-3457
Book of activities using a candle to illustrate scientific processes such as energy, burning, evaporation, convection, solubility, the candle as a clock, and more.
$8.95

Capsela Scientific
Sanyei America Corp.
450 Harmon Meadow Blvd.
Secaucus, NJ 07094
201-864-4848
A hands-on physical science curriculum containing the capsela motorized gearing system and 25 lessons with teachers notes, overviews and handout sheets.

Center for Applied Research in Education
Route 59 at Brookhill Drive
West Nyack, NY 10995-9900
Contains over 175 exciting activities and is divided into four sections: Teacher-directed activities, Life Science Activities, Earth Science Activities, and Answer Keys.
$24.95 plus handling

Challenges to Science: Earth Sciences
McGraw-Hill Book Co.
1221 Avenue of the Americas
New York, NY 10020
"Cloud Chart." Cloud Chart, Inc. Up to 50 free weather charts available from What's Your Weather IQ (Taylor Scientific Consumer Instruments, Div. Corp., Glenn Bridge Rd., Arden, NC 28704).

Choices, Decisions, Actions
Standard Oil Co
P. O. Box 5910-A
Chicago, IL 60680
A folder of activities for a program about careers in engineering and science.

Classifying Animals Warm/Cold Blooded
A. Gaines
PO Box 433
Fairfax, SC 29827
Tapes, games, activities prepared by teachers about birds: their sounds, feet & bills, their habitats, and the different kinds of birds.
$30.00

Colorado Futurescience, Inc.
Colorado Futurescience, Inc.
P.O. Box 17179
Colorado Springs, CO 80935
719-634-0185
Kits for making high-temperature superconductors and superconductor demo kits.

Colossal Fossils/Super Sea Shells
Educational Insights
Dominguez Hills, CA 90220
Discovery collections of 14 or more hands-on fossils/seashells. It contains activity cards, a magnifying glass and booklet.

Come With Me Science Series
S/S Publishing Company
3550 Durock Road
Shingle Springs, CA 95682
916-677-1545
Catalog of teaching modules, bulletin board kits, books, puppets, games, stamps and cassettes. Some science units come with songs to enhance memory building.
Catalog available to students and teachers.

Convection: A Current Event
Great Explorations in Math and Science
Lawrence Hall of Science University of California
Berkeley, CA 94720
415-642-7771
Guide containing lesson plans on tracing the convection currents in water, observing convection in air, movement of magma, continental drift and the sun.
Guide $6.50

Crime Lab Chemistry
Lawrence Hall of Science
University of California
Berkeley, CA 97420
Using technique of chromatography, students assume role of crime lab chemists to determine which blackpen was used to write ransom note.Grades 4-8.

Didactico
Didactico
P.O. Box 254768
Sacramento, CA 95865
916-485-5566
Permanent magnets: kits or miscellaneous. Activity booklet:magnets-Exploring the Mysteries of Magnetism, a hands-on approach.

Dinosaur Kit
Cristal Lehrmittel CMBH
Bergstra Be 11 5449
Schnellbach, West Germany
Archeological kit. Children excavate a fossil dinosaur by digging through a prototype sedimentary rock.

Dinosaurs and Prehistorics Flash Cards
Trend Enterprises, Inc.
PO Box 64073
St. Paul, MN 55164
A set of twenty-six flash cards on different types of dinosaurs.
$3.55

Dinosaurs: A Journey Through Time
Pacific Science Center
200 Second Avenue North
Seattle, WA 98109
206-443-2001
Activity book on identifying the characteristics of a variety of dinosaurs, making a geological time scale, interpreting dinosaur tracks, and constructing dinosaurs.
$9.95

Discovery Corner, Lawrence Hall of Science
University of California
Lawrence Hall of Science
Berkeley, CA 94720
415-642-7771
Catalog of scientific toys, tools, games and demonstration kits.
Write for catalog.

Discovery Science Kit
Kaplan School Supply Corporation
PO Box 609
Lewisville, NC 27023-0609
Kit designed for discovery and learning. It contains activities on time/measurements, magnets, animals/insects, and color/light.

Diving Into Oceans, Ranger Rick's NatureScope
National Wildlife Federation
8925 Leesburg Pike
Vienna, VA 22180
703-790-4000
Guide of 19 lessons that introduce children to the physical properties of the sea, it's habitats, and the interactions between people and the marine environment.
Guide: $6.00

Elaborations: Science Labs for Intmd. Students
Idea Factory, Inc.
10710 Dixon Drive
Riverview, FL 33569
813-677-6727
Collection of 20 activities for physical science and life science courses.
$16.99

Electricity Choices
Agriculture and Natural Resources
1205 Pendleton St
Columbia, SC 29201
803-734-0445
Series of five energy resources booklets with teachers guides, pre and posttest, student readings and questions and flash cards. Available as: Energy in Physics, Energy in Earth Science, Chemistry or Biology.
Free of charge.

Elementary Earth Science Sourcebooks
Center for Science Education
University of South Carolina
Columbia, SC 29208
803-777-6920
There are two books in this series: one for grades 1-3 and the other for grades 4-6 version. Each contains many inquiry-oriented earth science activities. Each district has copies, contact Center for additional copies.

Elementary Science Study of Nature
Lawrence Livermore Laboratory
Livermore, CA 94550
Program including teacher's guide, student worksheets, and experiments in the fields of physics, electricity and magnetism, chemistry, and biology.

Energy Concepts, Inc.
Energy Concepts, Inc.
7440 N. Long
Skokie, IL 60077
Complete classroom training systems on exploring technology and the principles of technology.

Energy Education Guidebook
Office of Energy Programs
1200 19th St, NW
Washington, DC 20506
Guidebook for energy education. Contains activities and projects for all grade levels.

Entertaining Science Exps. with Everyday Objects
Dover Publications
31 East 2nd Street
Mineola, NY 11501
More than 100 entertaining stunts that teach scientific principles as well as amuse and astonish, and requiring no special equipment that cannot be found in the average home.

For 8-TO-11-YEAR-OLDS
Delta Education, Inc.
PO Box M
Nashua, NH 03061-6012
800-258-1302
Module of nine activities: Ants, Attract a Fish, Bugs, Worms, and Others; Children go outside to explore these animals.

Fun With Physics
National Geographic Society
17th and M Streets, NW
Washington, DC 20036
202-857-7000
Book on the relationship of physics to everyday occurrences. Investigate sound, color, jumping, speed and acceleration, light, ice cream, and other common things.
$8.50

Gee Wiz
Little, Brown and Company
34 Beacon Street
Boston, MA 02108
800-343-9204
Book on basic science concepts: Children explore exploding colors, fantastic elastics, capillary action, surface tension, unmixable liquids, vision, magnification, symmetry, balancing, and forces.
$7.95

Hach Company
PO Box 389
Loveland, CO 80539
303-669-3050
Dozens of test kits, portable and lab instruments, chemicals, reagents, and labware.

Hide a Butterfly
Great Explorations in Math and Science
Lawrence Hall of Science, Univ. of Calif.
Berkeley, CA 94720
Science material for the study of birds and butterflies. Students create mural, make puppets and perform a play.
$6.00

Idea Factory's Super Science Sourcebook
Idea Factory
10710 Dixon Drive
Riverview, FL 33569
813-677-6727
Book of 100 lessons and activities for life, physical and earth science courses.
$19.95

Messing Around W/ Drinking Straw Construction
Little, Brown & Co., Inc.
34 Beacon Street
Boston, MA 02106
Fundamental engineering principles illustrated through construction of simple houses, bridges, and other structures from drinking straws.

Mini Volts & Wastey Watts Kit
Agriculture and Natural Res/Governor's Div.
1205 Pendleton St., Room 320
Columbia, SC 29201
803-734-0445, 734-1740
Kit on electricity and conservation. The kit includes, teacher's guide, coloring book, bulletin board, flash cards and cut-out "energy dolls"
Free of charge.

National Teaching Aids, Inc.
National Teaching Aids, Inc.
1845 Highland Ave.
New Hyde Park, NY 11040
516-326-2555
Catalog of lesson sets, microslides, film slides, models, and kits on the following topics: Cells, bacteria, plants, animals, human biology & health, reproduction, the biosphere, earth science.
Write or call for catalog.

Nature Activities for Early Childhood
Addison-Wesley Publishing Company
1 Jacob Way
Reading, MA 01867
800-447-2226
Book of 44 projects/activities on the following topics: animals, plants, or nonliving things common to almost all areas.
$11.40

Nuts and Bolts: Guide to Science Fair Projects
Science Man
4738 North Harlem Avenue
Harwood Heights, IL 60656
312-867-4441
Book helps teachers to guide students through selection, organization, implementation, and presentation of a creative and scientific project.
$6.95

ORBIX Corp
6329 Mori St
McLean, VA 22101
Educational toys/games/puzzles with applications to physics, optics, and calculus. Kit containing activity cards and guide. Children develop science process skills as they examine the human senses.
$27.00

Outdoor Areas as Learning Labs CESI Sourcebook
Eric Clearinghouse Science, Math, Envir & Ed
Ohio State University, 1200 Chambers Rd 3rd Floor
Columbus, OH 43212
614-292-6717
Book of activities about playground puddles, melting snow, common plants and animals, weeds, lawn grass, and other things. $6.50

Pacific Science Center
Pacific Science Center
200 Second Avenue North
Seattle, WA 98109
206-443-2870
Activity books for supplementing marine education. Topics include: ocean beaches, tides, profiles and ocean life or marine biology.
Write for list. Prices vary.

Processes in Learning and Understanding
Nystrom Division of Herff Jones, Inc.
3333 Elston Ave.
Chicago, IL
Science Kits that include worksheets, labcards, and laminated diagrams are available for topics: Science around us, Systems of the body, and earthworms.

Project Learning Tree Activity Guide
SC Forestry Commission
5500 Broad River Road
PO Box 21707
Columbia, SC 29221
Activities that teach children about the forest environment.

Projects: The World of Science
Facts on File
460 Park Avenue
New York, NY 10016
800-322-8755
Book divided in four sections: Puzzles, Codes, and Computers; Looking at Earth and Space; Experiments and Inventions; and Looking at Nature.
$9.95

Project Wild
Project Wild Aquatic
SC Department of Wildlife and
Marine Resources
Rembert C. Dennis Building
PO Box 167
Columbia, SC 29202
Activities that teach children about wildlife, wildlife habitats, and aquatic environments.

Safe and Simple Electrical Experiments
Dover Publications, Inc.
180 Varick Street
New York, NY 10014
800-223-3130
Book of 101 investigations exploring static electricity, magnetism, electrical current, and electromagnetism using a comb, dancing soap bubbles and magnetic boats, electricity from a lemon, etc.
$14.00

Salt Crystal Garden Kit
Bradley Products, Inc
PO Box 201405
Bloomington, MN 55420
612-881-1430
A complete salt crystal garden kit.
$9.00

Science Activities in Energy
Oak Ridge Associated Universities
P. O. Box 117
Oak Ridge, TN 37830
A series of activities designed to illustrate principles and problems related to various forms of energy, and their development, use, and conservation: Chemical Energy, Conservation, SolarEnergy, and Wind Energy.

Science Experiments You Can Eat
Harper & Row
10 East 53rd Street
New York, NY 10022
800-242-7737
Book of 39 science experiments where students investigate the composition of foods, how foods are processed, and how cooking changes food.
$4.95

Science From Water Play
Teacher's Laboratory
PO Box 6480, 214 Main Street
Brattleboro, VT 05301-6480
802-254-3457
Book of activities where children explore floating, sinking, capacity and volume through water play.
$8.95

Science Resources for Schools
American Assoc. for the Adv. of Science
1333 H street NW
Washington, DC 20005
Series of science activities, teacher's guide, and a leaflet on science careers. Activities include: Fluid patterns, popping corn, structure, motion in space, and more.

Science on a Shoestring
Addison-Wesley Publishing Company
1 Jacob Way
Reading, MA 01867
800-447-2226
Book of 50 investigations about scientific methods; change; and energy, fields, and forces.
$16.00

Scienceworks
Kids Can Press
585 1/2 Bloor Street West
Toronto, Ontario, Canada M6G 1K5
416-534-6389
Book of 65 experiments that include: testing body strength, ice fishing, making moebius strips, making low-energy breakfasts, flying airplanes, making butter, invisible ink, magnetic images, and various structures.
$7.95

Scott Resources
Scott Resources
P.O. Box 2121B
Ft. Collins, CO 80522
800-289-9299
Catalog of earth science materials: rock collections, charts, video tapes, activities and models.

Scriptographic Booklets
Channing L. Bete Co., Inc.
200 State Road
S. Deerfield, MA 01373-0200
1-800-628-7733
Publishes activity books on energy related topics: My Book, Coloring and Activities Book and Information and Activities Books.

Sea Sampler: Aquatic Activities for Classroom
SC Sea Grant Consortium
287 Meeting Street
Charleston, SC 29401
803-727-2078
Activities for the field and classroom to engage students in hands-on experiences in the coastal and marine environments. $4.00

Seasoning Math & Science
AIMS
PO Box 7766
Fresno, CA 93747
209-291-1766
Activities using estimation, graphing and problem solving. Teacher's edition has 22 investigations, each with lesson plans, background information, and extensions. $10.95

Seeds and Seedlings
Teacher's Laboratory
PO Box 6480, 214 Main Street
Brattleboro, VT 05301-6480
802-254-3457
Activities Book for children to observe, classify, experiment, measure, make and test hypotheses, control variables, and share information while working with seeds and seedlings. $8.95

Seeds and Weeds Unit
Creative Publications
Order Dept., 5005 Willoth Street
Oaklawn, IL 60453
Guidebook of 28 activities on the investigation of seeds-how they travel and plant themselves. Students plant seeds, observe growth and development. $8.25 for guide

Super Science Activities: From Master Teachers
Dale Seymour Publications
PO Box 10888
Palo Alto, CA 94303
800-872-1100
Book of activities on physical, earth, and life science topics. Students invent a seismograph, build a working battery, and create a balanced ecosystem in an aquarium. $15.95

TREEmendous Activities for Young Learners
Idea Factory
10710 Dixon Drive
Riverview, FL 33569
813-677-6727
Activities on the following topics: trees, identify how people and animals benefit from trees, the parts of a tree, how trees are used as shelters, and learn about some plants that live in or on trees. $8.95

The Book of Where
Little, Brown and Company
34 Beacon Street
Boston, MA 02108
800-343-9204
Book of activities, puzzles and stories on geographic locations around the world or the neighborhood in which they live. $7.95

The Curious Naturalist
Prentice Hall
Route 9W
Englewood Cliffs, NJ 07632
201-592-2000
Book on common plants and animals; divided into four sections, each devoted to subjects of interest during particular seasons of the year. $12.95

The Everyday Science Sourcebook
Dale Seymour Publications
PO Box 10888
Palo Alto, CA 94303
800-872-1100
Book of 1000 activities. The book is divided into six categories: Inorganic Matter, Organic Matter, Energy, Inference Models, Technology and Instructional Apparatus, Materials, and Systems. $18.95

The Reasons for Seasons
Little, Brown and Company
34 Beacon Street
Boston, MA 02108
800-343-9204
Book of Activities: make solar collectors, garbage gardens, worm farms, ginger beer, crystals, etc. This book is about the earth - projects, ideas to ponder, stories, and things to collect, explore, and change. $7.70

The Science Book
Workman Publishing Company
1 West 39th Street
New York, NY 10018
800-772-7202
Activities on pests, animals, people protista, and plants, investigate the 5 senses, and thoughts, while working on puzzles, observing specimens, experimenting, building habitats, or reading information. $7.95

The Science Man
PO Box 56036
Harwood Heights, IL 60656
312-867-4441
Supplier of science resource books. The author describes the whys, wherefores, and how-tos on creating inventions. Good Apple catalog also available: books, software, and games.
$8.95

Wetlands Are Wonderlands
Illinois-Indiana Sea Grant Program
65 Mumford Hall, 1301 W. Gregory Drive
Urbana, IL 61801
4-H Youth Project designed for youths interested in learning/doing aquatic science activities that can help the environment. Full of activities.

What Will Happen If....
Women's Educational Equity Act
Educational Devel. Ctr. 55 Chapel Street
Newton, MA 02160
Activities to help teachers incorporate math, science, and technology into the daily life of the classroom, focusing on the physical sciences.

Appendix C

Supplementary Articles

The Learning Cycle

By Charles R. Barman and Michael Kotar

Class, you'll notice that I've given each lab group a D-cell battery and battery holder, a flashlight bulb, and a piece of insulated wire," Ms. Smith began. "Using these materials, I'd like you to light the bulb." As the students succeeded in lighting their bulbs, she asked them to explain how they had done it.

After students had shared ideas about their bulb systems, Ms. Smith introduced the terms *electric current* and *open* and *closed circuit*. She had students read about these terms in their science textbooks and then discussed the reading with them.

Finally, the students applied their knowledge of electric circuits to a new situation. Each group connected a switch and two new pieces of wire to their bulb system and created a closed circuit. Ms. Smith asked them to describe how the switch worked, and to try to explain how the light switches in the classroom turn the overhead lights on and off.

Three Distinct Phases

The steps in Ms. Smith's method may seem to be in reverse, but she was practicing a teaching strategy called the Learning Cycle to develop students' understanding of open and closed circuits. In the Learning Cycle, students engage in hands-on activities *before* being introduced to new terms or reading text material. The Learning Cycle originated in the Science Curriculum Improvement Study (SCIS) and has been effective as a teaching strategy that directly involves students in active investigative science experiences (Purser and Renner 1983, Saunders and Shepardson 1974, and Weber and Renner 1972). Here are the three distinct phases of the Learning Cycle strategy and their characteristics:*

Exploration. In the beginning of the Learning Cycle, students explore new materials and ideas. They make observations and collect data. The teacher assumes the role of facilitator or observer, posing questions and assisting students individually and in small groups.

Concept Introduction. During this phase, the teacher guides students in large group discussions. Together they organize observations and data collected during Exploration and try to find patterns that may exist. These patterns often reveal concepts being defined in the lesson. The teacher introduces vocabulary related to the concept and may rely on textbooks, audio-visual aids, and other materials to further develop concepts.

Concept Application. At this time, the teacher poses a new situation or problem that students can solve by applying or extending the new concept. This phase often involves students in additional hands-on activities that reinforce understanding of the concepts. As in the Exploration phase, the teacher works with individual students and small groups.

Integrating the Cycle

Teachers can incorporate the Learning Cycle into most existing science materials. Sample lessons illustrating the integration of this approach follow. In each example, the content found in an elementary science textbook is described and followed by the same lesson in the Learning Cycle format. Present these samples to your preservice teachers for their use.

Grade Two—Seeds

The textbook lesson contains information about different types of seeds. It presents photographs of various fruits, flowers, and seeds, as well as accompanying written material.

Exploration

You will need

- several different types of seeds
- and a magnifying lens for every two students.

Display the seeds for students to observe with the magnifying lenses. Ask them to identify similarities and differences among the seeds.

Concept Introduction

Encourage students to discuss their observations and to list the physical properties of the seeds they viewed. Then have them read the textbook material about different types of seeds.

Concept Application

You will need

- different types of fruit,
- a magnifying lens for every two students,
- and a knife to cut the fruit.

Ask your students to observe the dif-

Teaching Teachers is a column of practical teaching methods for preservice teachers. If you have an idea that you think could benefit your fellow teachers in their understanding of science and/or teaching, send your manuscripts to column editor Michael Kotar, Dept. of Education, California State University, Chico, CA 95929.

*SCIS uses the names Exploration, Invention, and Discovery for the three Learning Cycle phases. We have renamed the second and third phases to more accurately characterize what happens in each of these segments.

ferent kinds of fruit (uncut) and to predict what type of seeds they think are in each piece. Have them explain their predictions, and discuss the various ideas presented. Then cut each fruit in half to expose its seed(s). Ask students to examine the seeds with a magnifying lens and to compare their observations with their predictions.

Grade Four—Inclined Planes

The textbook explains how moving an object up a ramp requires less force than lifting the object, introduces the terms *inclined plane,* and tells how differences in force relate to ramp steepness. Two brief activities follow the reading.

Exploration

You will need

- boards or cardboard for ramps,
- books to stack up and support ramps,
- toy cars and trucks or other objects to drag up ramps,
- and spring scales to measure force.

After students have set up their ramps, ask them to measure and record the force required to lift an object with the spring scale. Then have them pull the object up the ramp with the scale and measure and record the force. Ask students to repeat this procedure with other objects.

Concept Introduction

As students share their data, compile a chart of their force measurements. Encourage the class to look for patterns in the data and to notice that the force required to pull an object up a ramp is less than the force required to lift the object. Introduce the terms *inclined plane* and discuss examples of planes. Ask students how the required force would differ if the ramp were steeper. Assign textbook readings that deal with inclined planes for additional information and examples.

Concept Application

You will need the materials from the Exploration phase, with additional books.

Have students select an object and measure and record the force required to lift it. Then ask them to set up a low ramp and to measure and record the force required to pull the object up the ramp. Next, have them add books to increase the incline of the ramp and to measure and record the force required to pull the object up again. Ask them to repeat the process using even more books. Direct students to organize the new data and to look for a pattern. Then discuss with them the effects of steepness on the force required to move an object up a ramp.

Step by Step

Most elementary science lessons are relatively easy to modify into Learning Cycle lessons. Hands-on activities suggested by textbook authors often work well near the beginning of the lesson to form the Exploration phase, and enrichment activities are sometimes appropriate for the Concept Application phase. Science sourcebooks also describe additional investigative activities.

Tell preservice teachers that they might find it appropriate to complete a Learning Cycle in one class session, or they may wish to extend it over several

sessions for optimum enrichment. They should keep in mind that the important feature of the Learning Cycle is the real science experience it provides students.

Give preservice teachers these guidelines for modifying lessons into the Learning Cycle format:

- Select the lesson you want to teach.
- Refer to the Learning Cycle Check List (see fig.) to determine what components of the Learning Cycle are not included in the lesson you are modifying.
- Supplement the missing parts by drawing from appropriate resources. (Example: science activity books for Exploration and Concept Application phases; audio-visual materials and supplemental written materials for the Concept Introduction phase.)
- Sequence lesson components according to the Learning Cycle format.
- Use the Learning Cycle Check List to evaluate your new lesson.

To fully comprehend the Learning Cycle strategy, inservice and preservice teachers should actually work through student activities, compare traditional textbook lessons with Learning Cycle lessons, practice the steps used to modify a lesson into the Learning Cycle format, and modify and teach Learning Cycle lessons (Barman 1987; Barman, Cooney, and Leyden 1986).

Application of the Learning Cycle to elementary science materials gives students the opportunity to engage in hands-on activities before they are introduced to new terminology and concepts. Learning Cycle lessons also help students develop essential science process skills and give them a chance to apply scientific concepts directly, thus creating more meaningful learning experiences.

Resources

Barman, C.R. (1987). *Science, children, and learning.* Indianapolis: Author.

Barman, C.R., Cooney, T.M., and Leyden, M.B. (1986). *Learning about thinking and thinking about learning.* Indianapolis: Indiana University Foundation.

Karplus, R., and Lawson, C.A. (1974). *SCIS teacher's handbook.* Berkeley, CA: Science Curriculum Improvement Study.

Purser, R.K., and Renner, J. (1983). Results of two tenth-grade biology teaching procedures. *Science Education, 67*(1), 85–98.

Saunders, W., and Shepardson, D. (1974). A comparison of concrete and formal science instruction upon science achievement and reasoning ability of sixth-grade students. *Journal of Research in Science Teaching, 24*(1), 39–51.

Weber, M., and Renner, J. (1972). How effective is the SCIS science program? *School Science and Mathematics, 72*(8), 729–734.

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Learning Cycle Check List

This check list will help determine whether teaching plans contain specific components of the Learning Cycle format.

I. FOCUS*

1. The concept(s) to be taught are clearly identified.
2. The performance objectives are clearly stated.
3. The process skills that students use in the lesson are identified.

II. EXPLORATION PHASE

4. The Exploration Phase is activity oriented.
5. Ample time is provided for the exploration activity.
6. The exploration activity provides student/student and student/teacher interaction.

III. CONCEPT INTRODUCTION PHASE

7. The concept(s) introduced are an outgrowth of observation in the Exploration Phase.
8. The concept(s) are named, and appropriate vocabulary is developed.

IV. CONCEPT APPLICATION PHASE

9. Students extend concept(s) to a new situation.
10. Appropriate activities are used to apply the concept(s).

*FOCUS has been added to assist in planning each lesson. The Learning Cycle will lose its effectiveness if students are given this information.

THE LEARNING CYCLE: Making It Work

The Science Curriculum Improvement Study (SCIS), an elementary science program containing units of study organized around the learning cycle approach, has been found to be an effective teaching strategy (Weber & Renner, 1972) that can be successfully applied to other grade levels (Purser & Renner, 1983; Saunders & Shepardson, 1987; Stepans, et. al., 1988).

I have found the learning cycle to be particularly effective at the middle/junior high level. What follows is a description of this strategy and two middle school science lessons organized to follow that format.

The Learning Cycle

The learning cycle consists of three distinct phases: exploration, concept introduction, and concept application.* The characteristics of each of these phases are outlined below and illustrated in Figure 1.

1. *Exploration Phase*—In this first phase, the students are very active. During this time, they manipulate materials that the teacher distributes. The teacher plays an indirect role as an observer who poses questions and assists individual students and small groups of students.
2. *Concept Introduction Phase*—In this phase, the teacher assumes a more traditional role by gathering information from the students about their exploration experiences. This part of the lesson is also the vocabulary-building time when textbooks, audiovisual aids, and other written materials are used to develop the concepts.
3. *Concept Application Phase*—During this third phase, students must use what they've learned in the first two phases to solve a new situation or problem. As they did in the exploration phase, students engage in an activity.

These three phases of the learning cycle follow a well-defined pattern to assist students in developing new concepts. The exploration phase provides students with concrete experiences to help them build mental images of the new ideas or terms presented in the concept introduction phase. Then the concept application phase provides students with an opportunity to use these new ideas or terms in different situations, increasing the students' chances of internalizing them.

*The Science Curriculum Improvement Study used the terms exploration, invention, and discovery to describe the three phases of the learning cycle (*SCIS Teachers Handbook*, 1974). The last two phases have been renamed to more accurately characterize what happens in each of these segments.

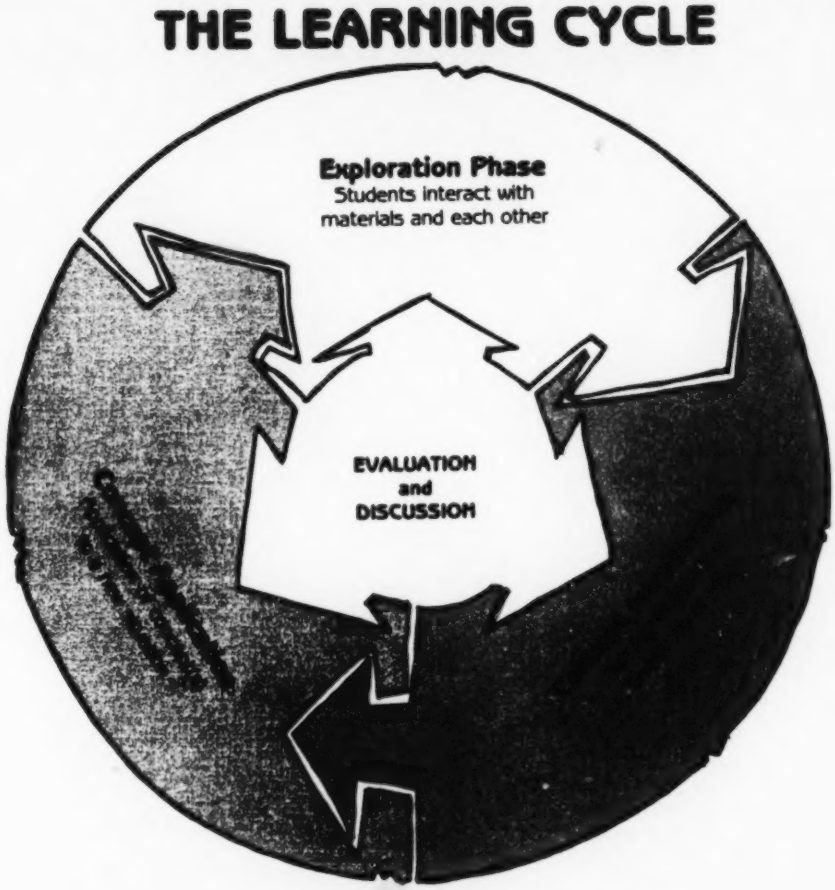


Figure 1.

Applying the Learning Cycle to Middle School Science

The following are specific examples of how the learning cycle can be incorporated into middle school science lessons. The first example may be used with a unit dealing with microorganisms or pond life, while the second lesson may be incorporated into an ecology module or a unit pertaining to soil and soil composition.

Example 1: Studying Pond Water

Exploration

Materials

- 1 sample of pond water
- light microscopes
- microscope slides and cover slips
- droppers

Procedure

1. Ask students to prepare several "wet mounts" of the pond water sample and to observe each slide under the microscope.
2. Have them make drawings of each organism they observe and share their findings with their classmates.

Concept Introduction

Procedure

1. Introduce the students to several organisms that are found in pond water. You may do so with a film showing a variety of one-celled organisms, 35-mm slides of one-celled organisms, and/or a textbook showing pictures of specific one-celled organisms and a description of each one.
2. Ask your students to identify any microorganisms they may have seen during the exploration phase.

Concept Application

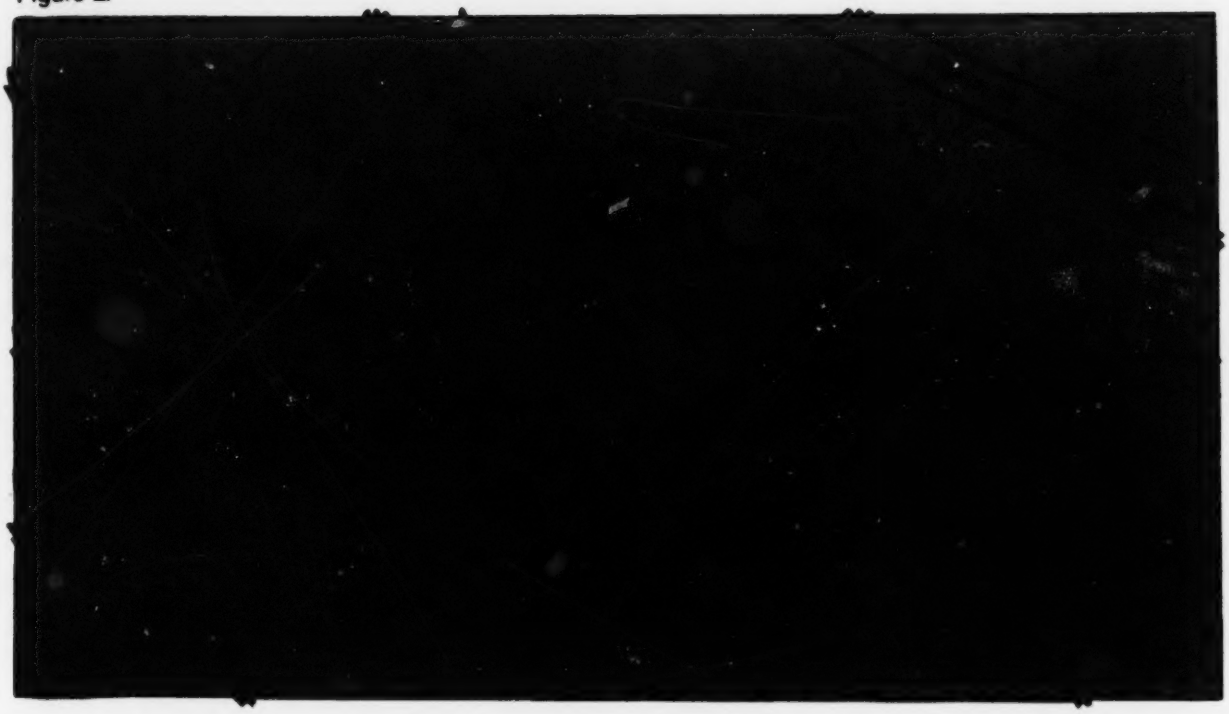
Materials

- 1 sample of pond water
- light microscopes
- microscope slides and cover slips
- droppers
- pond identification guides (e.g., *Pond Life*, Golden Press, New York, N.Y., 1967)

Procedure

1. Ask the students to prepare several "wet mounts" of the pond water sample and observe them under the microscope.
2. With the aid of one or more pond guides, have students try to identify specific one-celled organisms in the sample.

Figure 2.



Example 2: Studying Soil Characteristics

Exploration

Materials

(For each pair of students)

- 3 different soil samples (e.g., sand, clay, and loam) labeled A, B, and C
- 1 hand magnifying lens
- 1 graduated cylinder
- 3 short-stemmed funnels (65 mm in diameter)
- 3 test tubes (150 mm)
- 1 test tube rack
- 3 pieces of filter paper (11 cm in diameter)

Procedure

1. Ask students to examine each soil sample and record the color, texture, and relative particle size of each sample.
2. Next, have students place the test tubes in the test tube rack.
3. Ask students to insert a piece of filter paper into each funnel, and place one funnel in each test tube.
4. Now they are to half fill each funnel with a different soil sample, gently packing each sample to eliminate excess air spaces.
5. Ask students to pour 10 mL of water into each funnel and to measure the amount of water that drains through each of the samples in 23 minutes.

Concept Introduction

Procedure

1. Have students discuss their soil observations.
2. Following the discussion, introduce the terms *sand*, *clay*, and *loam* and explain the characteristics of each of these types of soil.
3. Then, have the students identify which soil sample was sand, clay, and loam.
4. Next, have students discuss the water-holding capacity of each type of soil and ask them to read appropriate material about how different soil types influence water drainage and runoff.

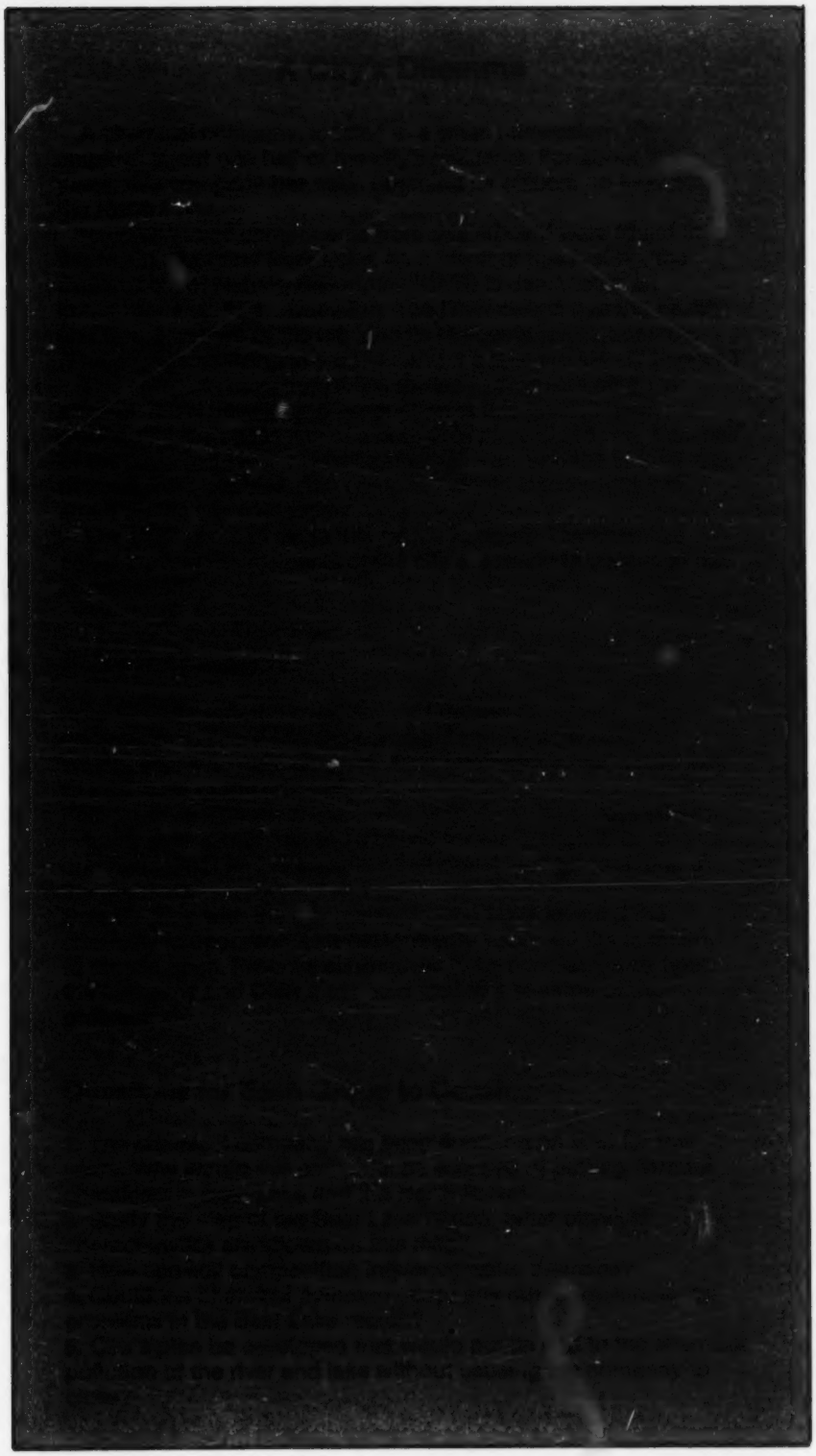
Concept Application

Materials

- 1 copy of map (Figure 2) for each student
- 1 copy of "A City's Dilemma" (See box on following page.) for each student

Procedure

1. Ask students to read the hypothetical story "A City's Dilemma." As they read this story, have them refer to the map you distributed.
2. Then divide the class into groups of four students each. Select two groups to assume roles 1 and 2. Role 3 may be assigned to more than one group.
3. Ask each group to select a moderator, an information gatherer, a technical advisor, and a spokesperson. The spokesperson and the technical advisor will be responsible for reporting the group's findings and recommendations to the entire class.



4. Be sure to allow ample time for group members to discuss their ideas before presenting them to the class. Encourage students to use the library to obtain information to support their arguments. At the end of the presentations, have the groups come to a consensus as to the "most suitable" solution to the problem.

Although the learning cycle was initially developed for use with elementary school children, the above examples show that this approach is very suitable for the middle/junior high grades. By using this approach, students are provided with appropriate activities before they are introduced to new terminology and/or concepts. In addition, students are given opportunities to apply these concepts to new situations, thus creating meaningful learning experiences for them.

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Wrap Up With a Writeup

Pencil this activity into your lesson plan—a daily journal just for science class.

By Gillian Kydd

Just after a hands-on science activity, children usually bubble over with enthusiasm. They want to tell others about what they have seen and found out. And they should—in wrjting. With pencil and paper, young students can share their experience with others, learn a little more about it themselves, and hone their writing skills simultaneously.

Tell Me About It

For the past five years, I have incorporated journal writing as a permanent part of my primary science program. My students, even those too young to know the terms for what they are observing, become highly motivated to write and share after they have finished an activity. As well, their science skills are reinforced as they reflect on what they did and what happened in order to put it on paper. Students' journals are also a big help to me in evaluating progress. Even children who appear to take part in the activity with little show of exuberance often reveal wondrous experiences in writing.

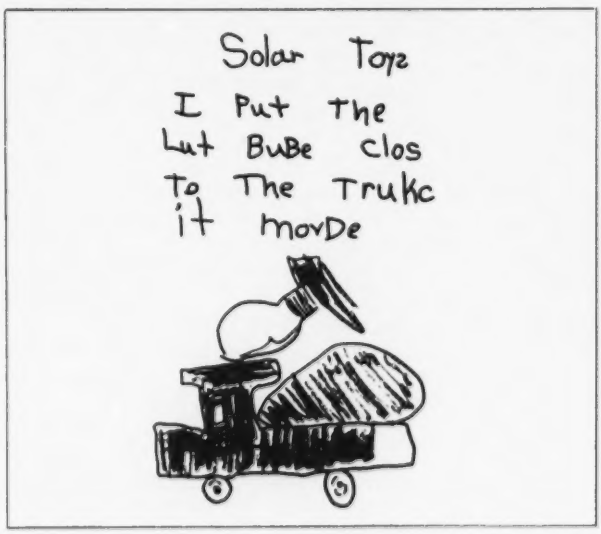
In my classes, science means studying a topic for four to six weeks, exploring a variety of materials at activity centers set up around the room. Students complete open-ended, challenging activities. I ask questions to assist them in working through the science process, and after they've visited the activity centers, I guide them in making their journal entries by asking them more questions. What did you do? What happened? What did you observe? What was the most interesting thing that happened in science class today?

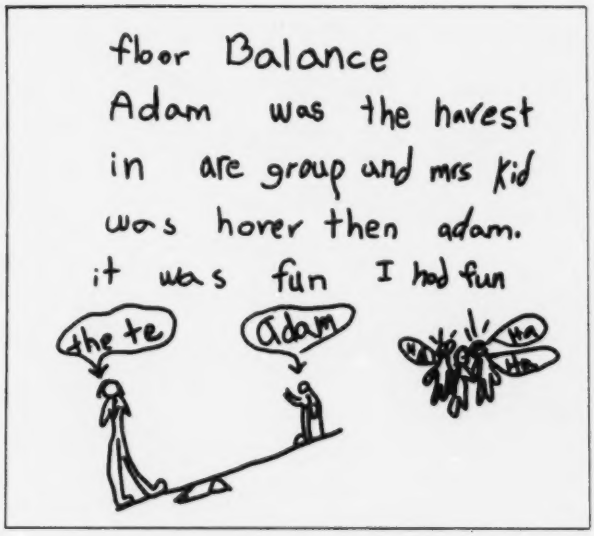
As they answer these questions, students must reflect on their newly learned skills. Young children are quick to observe, predict, make inferences, and solve problems—usually without realizing it. Journals solidify these process skills by making children think before they write.

All for Writing

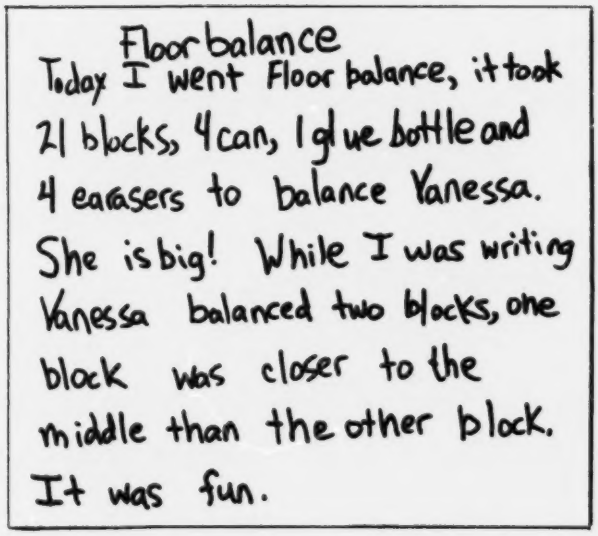
I've used the journal-writing approach with first, second, and third graders. In my experience, very young children

(Above) First grader Alexis diagrams her mealworm's path to his food. (Below) Alexander, another first grader, describes what happened to a solar toy when he put a light bulb nearby.





Julie, one of my second graders, illustrates the amusing fact that Mrs. "Kid" was obviously the heaviest.


Floor balance
Today I went Floor balance, it took
21 blocks, 4 can, 1 glue bottle and
4 earasers to balance Vanessa.
She is big! While I was writing
Vanessa balanced two blocks, one
block was closer to the
middle than the other block.
It was fun.

Third-grade student Melissa makes a detailed list of the items needed to equal the mass of classmate Vanessa.

are usually able to print the name of the activity and illustrate what they have done with a drawing. They also can dictate expressive words, which a classroom helper or a teacher then writes down. As the year progresses, many use "invented" spellings to write their reports.

Second graders tend to draw detailed drawings supported by several lines of writing. Soon, their writing develops greater importance than their drawings. They are creative and confident in their ability to write.

By third grade, some students write long, detailed accounts. They may not, however, take as many risks, and their writing is no longer as original. Many enjoy writing as a group and making group presentations.

Let Me Hear What You Wrote

Sharing the journals is an integral part of the science lesson. Children sit on the carpet and listen while a classmate reads from her journal. Beginning readers may pretend to read as they embellish their experiences with observations and discussion too advanced for their writing abilities. Often, there are drawings to share and to be admired as well.

During sharing time I probe the students with questions that extend their thinking. For example, I might ask a student, "Why do you think John looked upside-down when you saw him through the prism?"

Many children are influenced by their classmates' works. In multi-age groups, the younger children strive hard to copy the older ones. But best of all, the students are proud of their work. For a few moments, each is a star of the class.

I also encourage parents to participate in our science classes. With activity-based science lessons, the more adults there are, the better the program. Parents are instrumental in obtaining classroom materials and a big help to beginning journal writers who need to dictate their experiences to an adult.

I tell students who are writing on their own that I am more concerned about content than correct spelling—they should write the word the way it sounds to them. Soon, even the youngest students are writing on their own. They are thrilled when you can read what they have written.

Thoughts on Paper

Expressive journals are not the only form of writing encouraged in my science classes. Sometimes I have children record their observations in a chart, drawing, graph, short story, or poem.

Primary children are amazingly creative. They will see a new approach that older children miss, and they can more easily jump laterally in their thinking. A child might first use a balance as a see-saw, comparing one child's mass with that of another, until, suddenly, someone thinks of balancing himself with the objects piled on the end of the board. Student journals are an excellent way to capture the fleeting and sometimes extraordinary thoughts of young minds.

Gillian Kydd teaches at the University Elementary School, Calgary, Alberta, in Canada. Artwork courtesy of the author's students. Photograph on page 3 by the author.

USING INQUIRY TASK GROUPS IN ELEMENTARY SCIENCE

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The use of groups of students to carry out a scientific inquiry is an efficient use of people and materials. If you have a class of 24 to 30 students, you can involve students in group inquiry with only one-fourth of the materials you would normally use. In addition, research shows that students will learn interpersonal skills, improve personal responsibility and learn concepts as well as if they had conducted the inquiry activity individually. There are specific steps in using the group process. The following "do's" and "don'ts" have been developed by teachers while using inquiry task groups for several years in the elementary schools.

I. Structuring the Groups

At the beginning, the teacher will have to provide the structure and guidance to the groups. While the groups may vary from three to five in number, four is an ideal size and allows for work in pairs within the group. Job descriptions are essential and should be placed on the board and handed out to individuals within the groups.

II. Job Descriptions

The following five roles work well. For groups of four, compress the Recorder/Reporter functions into one. This group size seems to work best and gives everybody something to do during the activity. For outdoor activities, the Materials Manager/Maintenance Director role can also be combined to form a group of three.

PRINCIPAL INVESTIGATOR

The Principal Investigator is in charge of all operations associated with the inquiry. This means that the "PI" checks the assignment, asks informational questions of the teacher and conducts group discussions about processes and results. The PI is also in charge of group safety. The PI either conducts the activity or assigns the conduct of the activity to another group member.

MATERIALS MANAGER

The Materials Manager is responsible for obtaining and dispensing all materials and equipment for the inquiry activity. The "M&M" is normally the only student who will be up and down and moving around the classroom during the conduct of the activity.

RECORDER

Since data are collected during most inquiry activities, the Recorder is in charge of collecting the information and recording it on the worksheet, table, graph or other data collection instrument used in the activity. The Recorder in cooperation with the Principal Investigator and Reporter is also responsible for certifying the results that are recorded on the inquiry forms.

REPORTER

The Reporter is responsible for reporting the results of the group inquiry to the class. This can be an oral report given from his or her seat or a written report placed on a class summary instrument on the chalk board. The Reporter is also responsible for giving any group comments on the activity before the discussion of results begins.

MAINTENANCE DIRECTOR

The Maintenance Director is in charge of cleaning up the work station and, in completing this task, has the power to assign other members of the group to assist. When all materials and equipment have been collected, the "MD" can dispose of used consumables and clean up materials. The activity equipment is then turned over to the Materials Manager for return to the teacher's station.

III. Badges

Badges create a great deal of excitement and are invaluable in monitoring role performance. The students should have a role in constructing their badges. Many designs are useful and they may range from symbolic to highly formalized. Student or instant camera pictures may be attached and the entire badge laminated for strength and durability.

IV. The First Activity

This is a critical event. Choose a simple, interesting activity that can be completed in a short time. The learning of the student roles and how to function within the group are the instructional goals of this session. Science content and processes are secondary. If students are able to follow the procedures without problems, you are ready to begin some substantive lessons. If problems arise, debrief them in a whole class session and try again. The students will acquire the role behaviors quite rapidly.

V. Using a Model of Teaching

In beginning the group inquiry process, a highly structured model of teaching is preferable. As students learn the different roles and how they interact, a more individualized approach that both teacher and students are comfortable with will develop. The following steps in sequence will help you get started in using inquiry task groups.

1. INTRODUCTION

Introduce the lesson to the whole class. Use films, demonstrations or other techniques to set the stage for the group work. Answer all questions. If possible, write the inquiry on the board or on an activity card.

2. MATERIALS DISTRIBUTION

When all questions are answered, have the Materials Managers gather the equipment and materials. The "M&M" returns to the group work station and sets up the materials for the activity.

3. THE INVESTIGATION

The "PI" reads the directions, goes over the task, answers any group questions and begins the investigation. The teacher may move among groups at this time and provide limited assistance.

4. DISCUSSION OF RESULTS

The Recorder/Reporter brings the completed data or worksheet to the teacher who checks it for accuracy. The various group results are placed on the board and the teacher synthesizes the results showing similarities and differences.

5. GROUP CLEAN UP

This is a life saver. The Maintenance Director is in charge for each group and is allowed to distribute work to each team member. The goal is to have clean work stations with all materials and supplies returned to the storage area.

6. EVALUATION

You may want to give some individual test or measure after the clean up. You can do this with pencil and paper or in any appropriate manner consistent with your evaluation plan. You may also want to jot down some notes on how well individual students performed their roles. Finally, you may want to develop a short checklist for each student to fill out on themselves and each other.

V. TRICKS OF THE TRADE

* Let the groups choose names. It is a good social activity and helps you identify them.

* Change group members from time to time. Try boy-girl teams, introvert-extrovert, cultural and racial mixes.

* Talk only to the PIs about the activity. This will set up a chain of command and prevent the repetition of questions. The students should have meaningful discussions among themselves so that it will only be necessary for you to clarify points with the PI.

* Use groups both indoors and outdoors. The badges work well indoors, however, arm bands and headbands are more visible on the school ground. Hand held "walkie-talkies" are also useful and should be used by the PI.

* Use groups of three when working outdoors or on a field trip. This group size works better for safety and security purposes.

* Post class rules, group names, job descriptions and any other considerations on a bulletin board for clear communication.

* Develop a system for role rotation. This can be a poster or simply a rotational scheme for changing roles.

* Use the job descriptions for classroom management and discipline. Most of the time you will simply need to ask what person has which role to resolve problems.

* Use stickers for role identificaion on the student badges. This will allow them to change roles easily and often.

* Develop a worksheet, data recording sheet, graph or some other communication instrument for each activity.

* Make yourself a badge and join in the fun.

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Principal Investigator

Reporter

Materials Manager

Maintenance Director

Recorder

Recorder/Reporter

Cooperating classroom

By Jack Hassard

This article will be presented in two parts. The first part will discuss the evidence in favor of cooperative learning and explore four models of cooperative learning in detail. Next month, the author will describe his new model of cooperative learning developed especially for the science classroom. The material in this and next month's articles is based on the author's book, Science Experiences: Cooperative Learning and the Teaching of Science *(Menlo Park, CA: Addison-Wesley, 1990).*

During a recent two-year period I visited over a hundred schools in Arizona, California, Nevada, and Utah as part of a grant I had while at the Far West Laboratory for Educational Research in San Francisco. I observed that in spite of considerable evidence in support of student team-learning, students generally worked independently. In addition, the classrooms I visited contained very little evidence of the stuff of science teaching—rocks, straws, hand lenses, terrariums, plants, balances—and only four of the classrooms had a computer.

I realized that an alarming paradox existed with regard to elementary and middle level science: Small group, student-involved, hands-on science lessons motivate students and help them understand science, yet science lessons are usually teacher-directed to groups of observers.

A number of studies, as well as practical application, have led to a mountain of evidence that cooperative learning not only enhances social skills among students, but also enhances learning and cognitive development. David and Roger Johnson found that cooperative learning environments are superior to competitive or individualistic environments for fostering learning, self-esteem, and positive attitudes toward school and classmates.[1]

William Kyle reported that lessons implementing concrete learning materials and focusing on problem solving enhanced students' attitudes toward science and encouraged development of higher-level intellectual skills. Concrete, hands-on activities are the kind employed in many cooperative lessons.[2]

Cooperative learning is attractive to teachers because it enables students to learn from each other (in particular, high ability students can teach lower ability students). It offers an alternative to competitive learning which is disadvantageous to slower students and to students who have become "turned off" to school. Research has shown that small group learning may improve relationships between students from different ethnic groups,[3] and that cooperative groups, which structure learning around social interaction and verbal communication, can help girls overcome anxieties about science and math.[4]

Smaller classes would certainly enhance student learning. However, until money and space are made available for this, we are faced with improving learning while keeping class size constant. Breaking the class into small cooperative teams of two to seven students who work on tasks of varying types will create a new topology for the classroom and a potential solution to the problem stated above.

Selecting a strategy for your classroom

Cooperative learning is an instructional format in which students work together to achieve a particular goal or complete a task. A variety of cooperative learning models have been developed, field-tested, and evaluated. Some delineate how tasks are structured and how groups are evaluated. In some models, students work together on a single task; in others, group members work independently on one aspect of a task, pooling their work when they finish.

Groups may be evaluated in a variety of ways. In some models,

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the evaluation is based on the sum or average of individual members' performances; in others, the entire group's performance is evaluated. Methods of evaluation can stretch from traditional testing and grading to self-evaluation.

Some of the models are easy to understand and recreate in the classroom, while others may entail further research if they are to be implemented properly.

The four models I describe here fall into two broad categories: tutorial methods, and problem-solving and conceptual methods. Tutorial methods tend to be structured and teacher-centered, while problem-solving methods are open-ended and student-centered. Both approaches have been shown to be effective in helping students learn factual information and become better problem solvers.

Model 1: STAD

STAD was originated by Robert Slavin and his colleagues at Johns Hopkins University.[5] If you are interested in using cooperative learning in your classroom, STAD is an excellent model with which to begin, as it can be easily implemented into the traditional, textbook curriculum. STAD has five components outlined below.

- **Class presentations.** The class presentation is a teacher-directed presentation of the material—concepts, skills, and processes—that the students are to learn. The presentation can be a lecture, lecture/demonstration, or audiovisual presentation. Many textbook series include hands-on science activities within the text which could be an integral part of the presentation. If the material to be learned is a chapter in the textbook, you should plan several presentations.
- **Teams.** Teams are composed of four or five students who represent a balance in terms of academic ability, gender, and ethnicity. The team is the most important feature of STAD, and it is important for students to understand they will work together to help each other learn the material.

After the teams are organized, students complete approximately one lesson together, working with prepared study materials such as worksheets and workbook activity pages, or sets of questions based on the unit of study. Inform students that the worksheets are designed to help them help each other prepare for the quiz.

Each team of students works together to answer the questions. They can work in pairs within each team, and then the pairs can share their work. There are three ways to encourage team members to take responsibility for all of the work: 1) make sure that each member can answer each question correctly; 2) have students anwer questions on their own as often as possible; and 3) insist that team members explain their answers to questions.

- **Quiz.** After the work is completed, administer a quiz to measure the knowledge students have gained. Students take individual quizzes and are not permitted to help each other.
- **Individual improvement score.** To encourage students to work harder, assess an "individual improvement score." Establish a base score—the minimum score on the quiz—for each student. Individual base scores are determined by the teacher, based on each student's previous performances. To find the improvement score, calculate the difference between the base score and the student's actual grade. Compute team scores by adding the improvement scores of each team member.
- **Team recognition.** Recognize the work of each team in a newsletter, handout, or bulletin board that announces the team scores and the ranking of each team within the class. Report outstanding individual performances, too. Sensitivity is required here. You might identify several students each week, representing as many teams as possible. Improvement in learning is as important as the scores.

Cooperative learning not only enhances social skills among students, but it also enhances learning and cognitive development.

Praising students for academic performance has a positive effect on the way they perceive their abilities.

For more information on STAD, see *Using Team Learning*, by Robert Slavin (Baltimore: The Johns Hopkins Team Learning Project, 1986).

Model 2: Jigsaw II

Jigsaw II (developed by Eliot Aronson) is a cooperative learning model in which students become experts on a part of the instructional material about which they are learning.[6] By becoming an expert, and then teaching other members of their team, students become responsible for their own learning. The Jigsaw II model has the advantage of encouraging students of all abilities to be responsible to the same degree, although the depth and quality of their reports will vary.

Jigsaw II works especially well in

the science classroom because of the wide range of topics available. Try using it to investigate the systems of the body, study rocks and minerals, classify plants and animals, or to explore the solar system. Three important elements of Jigsaw II are outlined below.

• **Preparation of learning materials.** Develop an expert sheet and a quiz for each unit of study. If you are using a text series, this will be relatively easy. Divide the content into topics for the expert sheets. The expert sheet should communicate what students should do, such as read, watch a video, or do an activity, and it should also contain an outline of the topic in the form of questions.

• **Teams and expert groups.** In Jigsaw II, each student is a member of an expert group *and* a learning team. The expert groups are groups of team members studying the same topic. Distribute the expert sheets among each learning team and explain that each student will become an expert on some aspect of the unit.

Create enough expert groups so that each member of the learning team is assigned to a separate expert group. Give students time to work on their topic prior to meeting in their expert groups. The amount of time will vary, but generally one class period is sufficient.

Your expert sheets will be important, as they direct the students to activities, materials, and questions. Encourage diversity in learning methods. Groups might do hands-on activities, read from source books, or use a computer for a game or simulation. The groups' goal is to learn about the subtopic and to prepare a brief presentation that group members will use to teach the material to members of their respective learning teams.

• **Reports and quizzes.** When the expert groups have finished their work, each expert returns to his or her learning team, and teaches the topic to the other members. Encourage students to use a variety of teaching methods. They can demonstrate an idea, read a report, use the computer, or illustrate their ideas with photographs or diagrams. Encourage team members to discuss the reports and ask questions, as each team member is responsible for learning about *all* of the subtopics.

After the experts are finished reporting, conduct a brief class discussion or a question and answer session. Encourage experts to answer the questions. Then administer a quiz to each individual, using the same process of scoring and reporting described in STAD.

For more information on Jigsaw II, see *The Jigsaw Classroom*, by Eliot Aronson (Beverly Hills, CA: Sage Publications, 1979).

Model 3: Co-op Co-op.

Co-op Co-op[7] was developed by Spencer Kagan of the University of California, Riverside. Its philosophy is to "provide conditions in which the natural curiosity, intelligence, and expressiveness of students will emerge and develop."[8] The basic elements of Co-op Co-op are briefly outlined below.

• **Student-centered discussion.** Kagan suggests that students should have more say in what they learn. Thus, after the unit is introduced, a discussion is held during which students express their interests within the subject.

You can encourage brainstorming, but it is a good idea to keep a record of the brainstorming session by using colored marking pens on chart paper rather than a chalkboard.

• **Team selection.** A comparatively democratic method can be employed to establish the teams for Co-op Co-op, although students should join teams out of interest rather than out of friendship. However, letting students choose their groups increases their sense of responsibility. You can always regroup or discuss problems if they arise.

• **Topic selection and delegation of work.** Topic selection may be determined from the discussion or from a list of topics offered during the brainstorming session. (Have the teams select a topic from the list. It is important that the students generate this list.) Each team should select a different topic, but do not be concerned if there are more topics than groups.

The students will need to analyze the topic they have chosen so they can break it into minitopics. Each team member will be responsible for gathering information on the minitopic and sharing it with the team. Students can investigate their minitopics by gathering library information, doing a computer search, interviewing people, collecting materials, or finding experiments. Students should prepare a brief report to be presented to the team.

• **Team presentations.** One of the attractive features of Co-op Co-op is that each team makes a presentation to the whole class. Students have to cooperate to prepare a presentation. Encourage teams to prepare presentations that involve the audience, such as debates, demonstrations, hands-on activities, plays, or computer simulations.

During the presentation, the presenting team is responsible for setting up the room, gathering any equipment and materials, and preparing necessary handouts. Encourage the teams to allow at least five minutes for questions and comments from the class. In some cases, you should facilitate this aspect of the presentation.

• **Evaluation.** Evaluation can involve anything from no evaluation at all to a formal evaluation consisting of quizzes and graded reports. Somewhere between this is probably appropriate.

Have students evaluate their own presentations. Provide discussion questions, such as "What were the strong and weak points of the presentation," and "How would you change the presentation?" You can give feedback to each team or have the class evaluate each group presentation. A simple evaluation form can provide the team with recommendations that can be used to improve future presentations. No formal evaluation is required, and in some cases it is a good idea to let the learning and sharing be the reward.

For more information on Co-op Co-op, see *Cooperative Learning: Resources for Teachers*, by Spencer Kagan (Riverside, CA: University of California, 1985).

Model 4: Group Investigation

Developed by Shlomo Sharan and his colleagues, the Group Investigation method is one of the most complex forms of cooperative learning. Its philosophy is to cultivate democratic participation and an equitable distribution of speaking privileges. It also encourages students to study different topics within a group, and to share what they learn with group members and with the whole class.[9]

This method places maximum responsibility on the students, who identify what and how to learn, gather information, analyze and interpret knowledge, and share in each other's work. It is very similar to Co-op Co-op, and would have the greatest chance of success if students have experience with other forms of cooperative learning.

For a Group Investigation, form groups on any basis you or the students choose. A Group Investigation will incorporate the elements outlined below.

• **Topic selection.** Students organize into groups of five (or fewer) and choose specific topics in a general subject area. Each group plans its own topic and strategy for studying the topic. Then individuals or pairs within the group select subtopics and decide how they will pursue them.

• **Cooperative planning.** You and the students plan specific learning procedures, tasks, and goals consistent with the subtopics

(Continued on page 45)

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(Continued from page 39)
of the problem selected.

- **Implementation.** Students carry out the plans formulated in the second step. Learning should involve a wide range of activities and skills and should lead students to different kinds of sources, both inside and outside of school. You counsel the groups by following their progress and offering assistance when needed.
- **Analysis and synthesis.** Students analyze and evaluate the information gathered in the third step, and plan how it can be summarized in an interesting manner for a class presentation.
- **Evaluation.** You and the students evaluate each group's presentation and contribution to the work of the class as a whole. Evaluation can include individual or group assessment, or both.

For more information on Group Investigation, see *Cooperative Learning in the Classroom*, by Shlomo Sharan, et al. (Hillsdale, NJ: Lawrence Erlbaum Associates, 1984).

Fostering a learning environment

The superiority of cooperative learning environments over individualistic and competitive ones is evident in the research this article describes. However, people create learning environments, and teachers themselves determine the nature of the environment in which they use these strategies and methods. A number of social factors will affect the environment and therefore the success of cooperative learning.

Johnson and Johnson point out that cooperative learning environments are created when the teacher encourages a sense of positive interdependence among the students on a team.[11] Helping students learn how to divide the work load, decide upon a goal, and differentiate roles (i.e., record keeper, observer, experimenter, materials gatherer) are ways of creating positive interdependence. Physically rearranging the classroom so that students can sit and talk in small groups is a must. In addition, teachers must hold each individual in a group accountable for the material covered, and see that each student contributes to the achievement of the group's goal.

You will discover that, just as students learn science skills by doing science experiments, students will also learn communications skills (such as asking for others' opinions, listening, and explaining ideas clearly) when placed in a cooperative group.[12]

For more information on establishing a cooperative environment, see *Designing Groupwork: Strategies for the Heterogeneous Classroom*, by Elizabeth E. Cohen (New York: Teachers' College Press, 1986). ◼

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Teacher Notes